THE JOURNAL
OF THE
NATIONAL MALARIA SOCIETY

Including Proceedings of XXIV Annual Meeting

Published as an annual by the National Malaria Society
P.O. Box 997, Tallahassee, Florida

Domestic subscription price, $3.00 per volume, postpaid

NOTICES

The Society plans to expand the Journal to a quarterly of approximately 50 pages per issue as soon as financial support and sufficient contributed material justify such action. At that time application will be made to the postal authorities for second class mail rates.

Material for Submission:

Contributed papers on any phase of malaria or related subjects should be submitted to the editor. If suitable papers contain tables, require illustrations, or will require more than six pages in the Journal for publication, acceptance will be contingent upon the willingness of the contributor to assume the extra cost entailed by special typesetting; manufacture of cuts or over-run, which amounts are to be paid directly to the printer. Orders for reprints should be placed with the printers, and are to be attached to the galley proof when it is returned to the editor.

Pertinent advertisements will be accepted from reputable firms. Correspondence in relation thereto should be addressed to the secretary-treasurer.

Subscriptions

The Journal will be sent at time of publication to all members of the National Malaria Society whose dues for the current year are paid. It will be supplied members then in arrears when they terminate the delinquincy.

Subscriptions will be received from non-members and institutions at the rate of three dollars per annum from domestic subscribers, and three dollars and fifty cents from foreign subscribers. Subscriptions should be placed with the secretary-treasurer.

Revenue accruing to the Society from subscriptions will be wholly utilized for the support and enlargement of the Journal.

CONTENTS

CONTENTS
(Continued)

SPECIES ERADICATION[1] [2]

A Practical Goal of Species Reduction in the Control of Mosquito-borne Disease

Fred L. Soper

and

D. Bruce Wilson

The first application of anti-mosquito measures for the control of malaria and yellow fever, following the demonstrations (Ross 1898; Reed *et al* 1900) that these diseases are mosquito borne, was made by Gorgas in Havana, Cuba, in 1901. Since the measures applied were aimed at mosquitoes in general, all mosquito-borne disease was affected, but the striking reduction of the mortality from malaria was overshadowed by the dramatic disappearance of yellow fever. Similar comparative results were later observed for malaria and yellow fever, following general anti-mosquito measures in Panama (Gorgas 1910) and in Rio de Janeiro, Brazil (Oswaldo Cruz 1910). It is significant that the great American sanitarian Gorgas and the great Brazilian sanitarian Oswaldo Cruz, both worked to control malaria as well as yellow fever, but that the fame of each is based on results obtained with yellow fever rather than with malaria.

These early general anti-mosquito campaigns for the control of malaria and yellow fever were very expensive. Once it became apparent that the control of yellow fever is easier than, and independent of, that of malaria, it became customary to organize special yellow fever services for the control of *Aedes (Stegomyia) aegypti* breeding. Just as it was discovered that general anti-mosquito measures are not essential in the control of yellow fever, so also was

---

[1]The term "mosquito eradication" has been widely misused in the literature of mosquito campaigns where mosquito reduction is meant. "Species eradication" should be defined as the complete extermination of the species under consideration in all phases of its development: ovum, larva, pupa and imago. When species eradication has been accomplished, the crucial test of discontinuation of all control measures, in the presence of suitable breeding places, is not followed, in the absence of reimportation, by reappearance of the species.

[2]The work on which this paper is based was conducted with the support and under the auspices of the Ministry of Education and Public Health of Brazil and the International Health Division of The Rockefeller Foundation. The anti-aegypti campaign has been carried on for many years by a large number of colleagues on the staff of the Yellow Fever Service. For all practical purposes, the anti-gambiae campaign has been carried out by many of the same group, although under a special Service designated as the Malaria Service of the Northeast. More detailed reports of the organization and work of these two Services are in preparation.

it learned that malaria can often be controlled by attacking a single species of anopheline without consideration of other anophelines present in the community. Thus it came about that general anti-mosquito campaigns devoted to the solution of health problems have given way to special "species sanitation" (Watson 1911) campaigns: anti-aegypti campaigns for the control of yellow fever and special malaria campaigns taking as their objective the most dangerous local anopheline.

The program of such species sanitation campaigns has been one of reduction of the density of the individual species concerned below the critical threshold at which such species can continue to transmit disease under the existing local conditions. This report is based on such species sanitation campaigns against *Aedes (Stegomyia) aegypti* and *Anopheles (Myzomyia) gambiae,* in which "species reduction" has been pushed to its logical conclusion, namely "species eradication." The eventual great economy and administrative simplicity of species eradication over species reduction justify a careful study of all mosquito control projects to determine those in which the species eradication technique may be practicable.

Species Eradication of Aedes (Stegomyia) aegypti

Early campaigns for the control of mosquito-borne disease demonstrated that it is not necessary to eradicate vector species in order to curtail active transmission. Rather was it found that as the species density was lowered by control measures a "critical index" (Carter 1931) was eventually reached, after which transmission no longer occurred. This critical index is of course a variable function, depending on many factors other than the density of the vector, such as the incubation period of the etiological agent in the vector, the infective period of the human host, the development of lasting immunity, the number and distribution of susceptible hosts, and the number and distribution of sources of infection.

In dealing with aegypti-transmitted yellow fever, experience shows that generally the critical index has been reached when careful house-to-house inspection reveals the aquatic forms of the vector on not more than 5 per cent of the premises visited.[3]

In practice it was found during many years of anti-aegypti measures to be fairly easy to reduce aegypti breeding to the point where larval foci could be found in less than 5 per cent of the

[3]This house-breeding index is, of course, only a rough indirect measure of adult aegypti density, since it takes no account of the size nor productivity of the larval foci found. However, no figures are available, based on imago surveys during outbreaks of yellow fever, to determine the corresponding critical index.

houses in the area worked, but that attempts to force the house-breeding index below 1 or 2 per cent were very costly and that final species elimination was never obtained. In the light of this experience, yellow fever work came to be based on a program for the reduction of the aegypti house index to well below 5 per cent, but no attempt was made to secure complete eradication.

It was also found that any relaxation in the anti-aegypti measures resulted in a dangerous increase of aegypti production. The cost of the regular anti-aegypti services is high, so that funds for adequate services of this type were generally available only during and for a limited period following outbreaks of yellow fever.

A surprising result of the early anti-mosquito campaigns in Havana, Panama, Santos and Rio de Janeiro was that yellow fever disappeared not only from these cities but from surrounding areas as well. As long as yellow fever was believed to be only a human disease, transmitted by a single species of mosquito, it seemed logical to attempt the eradication of yellow fever from the American continent through temporary intensive campaigns in the principal cities of known endemic regions to reduce aegypti density below the critical index. No plans were made for permanent aegypti control measures since, once yellow fever disappeared from these principal cities, it would soon disappear also from the surrounding areas and not reappear unless imported from Africa.

This concept of the strategy of yellow fever control received a rude shock in 1928 when yellow fever appeared unexpectedly in Rio de Janeiro, the capital of Brazil, after an absence of twenty years. Although it was universally recognized that the modern development of Rio de Janeiro dated from the first notable campaign of Oswaldo Cruz, anti-aegypti measures had been practically abandoned after a number of years of freedom from yellow fever. The disease reappeared at a time when no nearby foci of infection were known and it was not until the discovery, a few years later, that yellow fever is also a disease of wild animals in the tropical forests that a satisfactory explanation of the origin of the reinfection of Rio de Janeiro became available. Jungle yellow fever constitutes a permanent source of virus for the reinfection of aegypti infested areas and makes the permanent eradication of yellow fever through a temporary reduction of the domestic vector, *Aedes aegypti,* impossible.

The Rio de Janeiro epidemic of 1928-29 forced a recognition of the danger of unchecked aegypti breeding in those centers of population within striking distance of infection. The develop-

ment of air transportation of passengers has so shortened the travel time between distant points that practically the entire world is threatened by the possibility of infective cases arriving from the endemic regions of Africa and South America during the incubation period which may be as long as six days. *While required vaccination of all air passengers may be of some value in protecting against this threat, the only guaranty of safety is elimination of the aegypti mosquito.*

Various solutions to the problem of the high cost of aegypti control have been suggested and tried in an effort to develop a program of permanent control. As early as 1927 the attempt was made to use monthly, instead of weekly, cycles of inspection in those cities in northeast Brazil where a low house-breeding index had been maintained for several years. This lengthened cycle permitted of a great reduction in personnel and in operating cost, but also permitted a dangerous increase in aegypti density and, eventually, yellow fever reappeared in some of the cities with such lengthened cycles.[4]

In 1928 a serious attempt was made to eradicate aegypti from Paraíba, at that time a city of some 35,000 people. This attempt failed, but produced the concept of the "mother," or "generating," focus as responsible for the perpetuation of the aegypti species in cities where anti-aegypti measures were being carefully applied.

It was reasoned that, since the aegypti mosquito is relatively short-lived, any prolonged perpetuation of the species must be due to hidden production not subject to elimination at the time of the inspector's regular visit. This reasoning was based on the fact that when low house indices are obtained, practically all of the foci found by the regular inspectors contain larvae only, the final aquatic or pupal stage being absent. When these larval foci were plotted on the map of the area worked, they were found to form clusters, each of which was the product of one or more near-by hidden primary foci. Searching out and destroying hidden foci in this way

[4]A given house-breeding index based on weekly inspections is correlated with a much lower density of adult aegypti than is a similar index based on longer inspection cycles. With a weekly cycle, the foci found are destroyed before they come to fruition, since the minimum cycle of reproduction of the aegypti mosquito is longer than the interval between inspections. With a monthly cycle, however, such foci may produce as many as three broods of mosquitoes between inspections. In the first case adult production is necessarily limited to such foci as are not found by the inspection, whereas in the second case there is added to this production of hidden foci, that which can occur during a month from observed foci. Thus a house index of 5 per cent on a weekly cycle may indicate the presence of relatively few adult mosquitoes at any one time, whereas the same index on a monthly cycle may correspond to a much higher adult density.

helped to reduce the already low index but did not alone lead to eradication.

Previous to the introduction of the search for adult aegypti to indicate the presence of this species, the officer in charge of yellow fever control had to rely on the larval index[5], based on foci found and reported by the inspectors who were themselves responsible for maintaining a low aegypti density. The inference is obvious.

In some tragic instances in which fatal yellow fever reappeared in controlled areas, it was found that the reported larval index utterly failed to represent the true breeding conditions. At times this discrepancy was due to careless work and often to failure to report conditions as found, but when well-trained chief inspectors and health officers repeated the inspection, even in areas worked by able and conscientious inspectors, an appreciable number of missed aegypti foci were generally found. Often, especially in areas where the total number of foci was low, the number found on reinspection equalled that reported initially. It eventually became apparent that the greater experience and imagination of those checking the work were often responsible for finding additional foci missed by the routine inspector.

On the other hand, it was found that when the regular inspector's visit occurred immediately after that of those checking his work, he sometimes uncovered foci missed by his superiors. In any case, the second inspection was merely a repetition of the first and both pitted human intelligence against aegypti instinct in the discovery of actual or potential hidden breeding places. In this struggle, instinct often won, the really difficult foci missed by the regular inspector being missed also by the checking inspector.

In order to get an independent estimate of aegypti density, a page was taken from the malariologists' handbook and the search for adult aegypti introduced towards the end of 1930. The adult capture method has proved to be the most sensitive indicator of the presence of aegypti in an area and is invaluable in locating the position of such hidden primary perpetuating foci as may remain after the gross infestation has been eliminated by routine antilarval measures.

At about the same time, effective measures were introduced to eliminate, as mosquito-producing foci, all water containers found with larvae, by destruction or by oiling with a mixture of three parts of fuel oil and one part of Diesel oil.

[5]Technically includes pupal foci as well, since most pupal foci also have larvae.

It is believed that the use of adult captures for the localization of hidden primary or generating foci and the routine destruction or oiling of all foci found, were responsible for the complete absence of aegypti breeding which has been reported from an ever-increasing number of Brazilian cities and towns over long periods since 1932 (see Table).

The first effect noted in the curves of mosquito indices following the introduction of adult captures for the location of hidden breeding was the gradual separation of the aegypti index from that of other mosquitoes. Previously, the indices of aegypti and other mosquitoes had fluctuated together throughout the year, according to the amount and distribution of rainfall and other climatic factors. Thereafter, however, the index of other mosquitoes continued to fluctuate, whereas that of aegypti tended to continue on a regular downward course, eventually reaching the base line (Soper 1937, pp. 669-671). It became evident that species reduction of aegypti was being carried to the extreme of species eradication without greatly affecting the breeding of other species of mosquitoes.

The use of the capture method brought some unexpected results, one of which was the modification of the handling of the "unoccupied house" problem. Previously it was found that the empty house constituted a serious problem in the reduction of aegypti breeding in an area. Since the empty house was generally locked at the time of the inspector's regular visit, such foci as might be present were not found and destroyed. Eventually the problem was handled by special empty house squads which carried special equipment and were responsible for getting the keys to all unoccupied houses, entering them and eradicating all potential aegypti foci so that further visits would not be required until the house was again inhabited. The work of these empty house squads was effective but expensive, and was in many cases devoted to aegypti-proofing houses which would not in any case have produced aegypti, either because of absence of potential foci or because of absence of aegypti in the immediate neighborhood to take advantage of such potential foci as did exist. With the introduction of the capture method it was found that examination of empty houses could be discontinued except when the presence of aegypti breeding in the neighborhood of such empty houses was revealed by the capture of adult aegypti in nearby houses where they had gone to feed.

The use of the capture method, followed by routine elimination of all foci found, revealed, as should have been self-apparent,

that though the number of potential breeding places of aegypti may appear to be almost infinite in certain areas, actually the number of permanent producing foci on which the species depends for its continued existence is finite. Such casual breeding places as roof gutters and flower vases are not generally responsible for maintaining the species.[6] Roof-gutter breeding may be a very important factor in building up a high adult density during the rainy season in cities where an otherwise low index has been obtained by control measures, but only occasionally do roof gutters form permanent primary foci, and the presence of these will be revealed by the finding of adult mosquitoes in the houses; it is no longer necessary to maintain costly routine roof-gutter inspection.

The first zero indices were obtained in 1932 and a sufficiently long period has now elapsed for sound conclusions to be drawn regarding the possibilities of aegypti eradication. In the early days of zero indices it was often found that a city which had apparently been free of aegypti for some time would be reported dirty again. Careful investigation showed that this reappearance of aegypti was often due to some householder putting water once more, sometimes after an interval of several months, in water jars on the walls of which were still viable eggs of aegypti. In contrast to this "internal" reinfestation, it was found in other cases that reinfestation had occurred from outside the clean areas by transportation of eggs or aquatic forms in the water containers of families moving from "dirty" areas, or through transportation of adult aegypti on trains or boats.

Experience showed that the internal reinfestation could be exhausted in time but that it was necessary to extend anti-aegypti measures to tributary communities to overcome the threat of "external" reinfestation. Such extension has been carried out on an ever larger scale, without increased expenditure, by suspending routine inspection in clean areas and using personnel thus released for work in dirty tributary areas. The capture of adult aegypti has proved to be an adequate indicator of reinfestations, internal and external, when such occur, in clean areas where routine inspections have been suspended.

As this program continues, the areas free of aegypti become

[6]This concept of selective breeding is important in considering other species which may appear to present insoluble problems because of the wide variety of conditions under which they may occasionally be found to breed. On careful investigation it will often be found that the effective breeding of the species in question, that is, the breeding which is responsible for the year after year maintenance of the species is limited to certain special types of containers or foci.

larger, the chances of reinfestation decrease, and the number of men available for work in remaining dirty areas increases in relation to the size of these dirty areas.

The search for adult aegypti is slow and expensive and is not used in the initial stages of a campaign while the adult aegypti density is high; its special purpose is the discovery of hidden breeding after the bulk of aegypti production has been eliminated by the routine anti-larval measures.

Administratively there is a great psychological advantage in undertaking species eradication rather than species reduction, and classifying each area as "dirty" or "clean," rather than as with "safe index" or with "dangerous index." The demand for 100 per cent efficiency removes the last defense of the inspector who does sloppy work; the basic question, "Is aegypti present?" requires an answer of but one word and cuts short all argument.

The great reduction in staff possible in a given community once eradication has been accomplished, and the reduced contact of this staff with individual households are conducive to administrative simplicity.

The table presents, in summary form,[7] quarterly reports of the actual number of premises[8] found with foci of aegypti in various cities of Brazil before and after the adoption of the program of species eradication.

In attempting to eradicate aegypti, it was found that certain cities, after some months' work, were almost clean, only to continue with a small number of foci every trimester; that other cities were very slow in acquiring relative cleanliness; while others, after being clean for some time, suddenly showed an appreciable number of foci. The trickle of an occasional focus in a clean city generally resulted from reinfestation from near-by dirty areas or even from distant areas by river boats (Manáos, Belém); the failure of a city to become clean in a reasonable period generally was the result of lax administrative supervision at a time when more serious matters were demanding attention elsewhere; and the sudden increase in the number of foci in a city, followed by their early disappearance, often

[7]More details of this work from 1935 to date have been published from time to time in the Boletín de la Oficina Sanitária Panamericana, Washington, D. C.

[8]The house-breeding index or percentage of houses found with aegypti foci is useful in estimating the possibility of yellow fever transmission and in comparing the situation of one "dirty" city with another. Once eradication is undertaken in an area, the interest shifts to a comparison of local conditions at intervals in the same area over a period of time. For this purpose the actual number of premises found with foci is a much more stimulating figure than is the house-breeding index, which often masks the trend of small numbers behind a series of decimal places.

Quarterly Summary of Houses Found with Aegypti Foci before and during Species Eradication Program

BRAZILIAN PORTS	Approximate population	Approx. number of houses	HOUSES WITH FOCI OF *AEDES* (*Stegomyia*) *AEGYPTI* — Before Species Eradication[1] — Year	Quarter 1st	2nd	3rd	4th	During Eradication Program[1] — 1938 — Quarter 1st	2nd	3rd	4th	1939 — Quarter 1st	2nd	3rd	4th	1940 — Quarter 1st	2nd	3rd	4th	1941 — Quarter 1st	2nd	3rd	4th
Manáos	63,574	13,753	1933		1218†	3068†	2458†	2	1	2	1	2	0	0	0	0	0	0	0	0	3	0	
Belém	159,088	32,405	1932	1182†	886†	571†	394†	0	3	1	0	0	2	0	0	0	0	2	1	0	0	1	
São Luiz	63,617	12,327	1931	1507†	2922†	3173†	1151†	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Terezina	40,248	9,650	1932	2794†	3892†	816†	330†	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Parnaíba	21,395	5,620	1933	512†	271†	126†	336†	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Fortaleza	122,273	28,206	1931	4265†	4494†	1795†	532†	6	4	0	1	0	1	1	0	0	0	2	0	0	0	0	
Natal	50,630	12,501	1931	7165†	8460†	4048†	1047†	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Macáu	7,469	1,966	1931			892†	627†	0†	1†	0†	0†	0†	0†	0	0	0	0	0	0	0	0	0	
João Pessôa (Paraíba)	74,134	12,645	1931	29	40	28	9	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	
Cabedêlo	6,322	1,704	1932	140†	151†	92†	44†	0†	0	0	0	0	0	0	0	0	0	0	0	0	0	0*	
Recife	333,600	76,684	1931	5626†	7449†	5231†	1779†	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Macció	74,723	20,765	1931	4787†	4052†	3042†	3464†	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Penedo	12,559	3,970	1931	437†	432†	276†	138†	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	
Aracajü	51,561	13,274	1931	142†	130†	115†	55†	0	2	0	2	0	1	0	0	8	2	0	0	0	0	0	
Salvadôr (Baía)	255,166	58,252	1931	3988†	3019†	2973†	2921†	2	0	0	0	1	1	0	1	0	1	0	1	0	1	0	
Ilhéus	19,035	4,985	1931	2724†	4150†	1767†	957†	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Vitória	61,635	13,586	1931		1864†	2455†	1677†	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Niterói-S. Gonçalo	193,449	45,632	1932	3133†	4773†	2934†	2051†	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	
Federal District	1,787,440	383,713	1932	451†	185†	71†	192†	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	
Santos	143,351	27,612	1935		190	0†		-	-	0	0	0	0	0	0	0	0	0*	0*	0*	0*	0*	
Florianópolis	33,680	5,257	1936		135†	10†	7†	2†	1	0	0	0	0	0*	0*	0*	0*	0*	0*	0*	0*	0*	
TOTAL	3,574,949	784,507		38,882	48,713	33,483	20,169	13	12	3	4	3	5	1	1	8	6	4	2	0	5	1	

[1]In the period "before species eradication" the number of foci found is appreciable in spite of weekly destruction; in period "during eradication program" the number of foci found remains low in the face of lengthened inspection cycles, generally 28 days.

†Weekly inspection.
*Regular inspection suspended; presence of aegypti checked by adult captures only.
All others, lengthened cycle, generally 28 days.

represented only an apparent increase, because of the inclusion in the control area of dirty suburbs not previously worked and which had been found to be dangerous sources of reinfestation.

The data presented in the table covers only a few of the more important centers worked among the hundreds, nay thousands, of cities and towns, villages, hamlets and even rural districts in which anti-aegypti measures have been applied in Brazil in recent years. Local species eradication of aegypti has been accomplished in many of the larger cities and even in entire states, and these have been protected against serious reinfestation for years at a time for but a fraction of the expense previously incurred in maintaining "safe" aegypti indices in a few of the larger cities. A large percentage of funds now charged to yellow fever control is devoted to the campaign against nuisance mosquitoes in cities where aegypti no longer exists. The development of a technique for the eradication of these nuisance species would permit of further great economies.

With regard to the possibilities of aegypti eradication, it can be said that no insoluble problems have been found in Brazil and that with the present organization and orientation of the National Yellow Fever Service of the Brazilian Department of Health, a few more years should find Brazil practically free of this species.

In the officially adopted "Internal Regulations" (1941) of this Service, the Section of Stegomyia Control is given the responsibility for:

"a. Preparing plans for the campaign against *Stegomyia* (*Aedes aegypti*) looking towards the complete elimination of this species . . . ." and

"c. Supervising the work of eradicating the vector (*Aedes aegypti*)."

Species Eradication of Anopheles (Myzomyia) gambiae

In 1930, following the discovery at Natal, Rio Grande do Norte, Brazil, of *Anopheles gambiae*, the most notorious of the African vectors of malaria, there were some informal discussions of the possibility of attempting the eradication of this newly imported species while the infested area was still small. No serious attempt was made, however, and the demonstration in 1931 that the species had spread to several points in the interior of Rio Grande do Norte led to the conclusion that eradication was no longer possible through the application of control measures, and to the reliance on the empty hope that this dangerous species would not find conditions in Brazil suitable for permanent residence and further dissemination.

In March 1931[9] a local anti-gambiae service for Natal was organized and before the end of the year control measures were extended to various points in the interior of the State.

The initial campaign against gambiae was essentially an anti-malaria campaign and once the malaria problem of the state capital was solved, no further measures were taken. This abortive attempt to deal with gambiae was of great importance since it may well have been one of the deciding factors of gambiae's failure to spread southward along the coast from the city.

Paradoxically enough, the success of anti-gambiae measures in Natal, instead of stimulating a continued program for the eradication of gambiae from the relatively small area infested in the interior of the state of Rio Grande do Norte, actually resulted in the neglect of this infestation until after it had assumed gigantic proportions in 1938.

During the period 1932 to 1937 inclusive, gambiae was but little in the public eye, although it was known to persist in the interior of Rio Grande do Notre. Apparently the Assú, Mossoró and Jaguaribe valleys were invaded about the same time, either late in 1936 or early in 1937. The year 1938 witnessed, in this region, what may well have been the most severe epidemic of malaria ever occurring in the Americas; official estimates give over 100,000[10] cases and a minimum of 14,000 deaths during the first six months of the year. The demand that something be done about this African invader was insistent and at the end of October, the Brazilian Government organized a control service with a budget for the rest of 1938 of one thousand contos ($50,000.00 U.S.) under the name of Service for Anti-Malaria Operations (SOCM). At the same time, the International Health Division of The Rockefeller Foundation undertook an independent survey (Shannon and Andrade, 1940) of the extent of the infested region and those factors which might in-

[9]At the request of the Director of the National Health Department of Brazil, the Cooperative Yellow Fever Service, maintained by the Ministry of Education and Health of Brazil and the International Health Division of The Rockefeller Foundation, undertook the organization of anti-gambiae measures in Natal to mitigate the effects of the second gambiae-transmitted outbreak of malaria in the New World, the first epidemic having occurred the previous year. In October 1931 the responsibility for the control of gambiae was taken over by the State Health Service of Rio Grande do Norte, under the direction of one of Brazil's best known malariologists who had been especially appointed because of the gambiae situation. The special budget of 300 contos ($20,000.00 U.S.) made available by the federal government to meet this problem was exhausted within a few months and control measures abandoned in April 1932.

[10]This estimate of cases is undoubtedly ultraconservative. In the following year the Malaria Service of the Northeast treated in the same region 176,000 persons, and probably failed to reach at least 25 per cent of the sick during the epidemic season.

fluence the success of a belated attempt to eradicate gambiae from the country.

On the basis of this survey and the experience of the Service for Anti-Malaria Operations, the Malaria Service of Northeast Brazil was created by presidential decree in January 1939, especially for the purpose of attacking the gambiae problem. The Malaria Service of the Northeast began the year's operations with a total budget of seven thousand contos ($350,000.00 U.S.), of which five thousand contos ($250,000.00 U.S.) were contributed by the Ministry of Education and Health and two thousand contos ($100,000.-00 U.S.) by the International Health Division of The Rockefeller Foundation.

The Malaria Service of the Northeast was, from the beginning, organized as an anti-gambiae service rather than as an anti-malaria service although sizeable sums and much effort were devoted to the treatment of fever cases during 1939 and the first half of 1940, in a humanitarian effort to reduce the mortality from malaria during the period of continued gambiae transmission. The chief objects of the service were, first, to learn how to eradicate gambiae and, second, to eradicate gambiae. The urgency of the situation and the shortage of technical personnel precluded any careful study of malaria.

The reasons for undertaking the eradication of gambiae and gambling such large sums as were eventually used on this effort can be understood only by those who have witnessed the effects of true epidemic malaria, which are many times more severe than are those of annual "epidemics" in endemic areas. The realization that the 1938 outbreak would be repeated over and over again in the same river valleys until the survivors among the local populations had become thoroughly malarialized and relatively immune, and that this tragic picture would be drawn in the same sombre tints in many parts of the Americas, as other suitable parts of the continent were invaded, one by one, left those who might, no choice but to attempt to eradicate the species, no matter what might be the odds against success. Factors which influenced the decision to make the attempt were:

1. The previous demonstration by the Yellow Fever Service that the eradication of *Aedes aegypti* is a practicable public health measure.
2. The failure of gambiae to persist in Natal itself or to re-infest the original focus of 1930 following the initial 1931-32 campaign.

3. The apparent limitation of gambiae to parts of the states of Rio Grande do Notre and Ceará where meteorological and topographical features might be expected to delay extension and favor eradication.
4. The existence of the large staff of well-trained men of the Yellow Fever Service, experienced in the species eradication technique as applied to aegypti, which could be drawn upon at will.

Among the many factors which suggested caution were:

1. Absence of adequate experience with methods which might be successful in dealing with gambiae.
2. Almost complete lack of encouragement from malariologists and others having experience in attempts to control many species of anophelines, including gambiae.
3. Lack of knowledge of critical points in the biology of gambiae, such as, duration of viability of ova, and hibernation and estivation of imagos.
4. Failure to find any record of species eradication of insects except that of the Mediterranean fruit-fly (Strong 1931) in the United States, against which intensive combat was begun immediately after its discovery.

No previous estimates were made of the time and money which might be needed to explore the possibilities of eradication. It was fully realized that the effort might well end in failure; none could foretell the rapidity nor the direction of spread of gambiae which might occur before control measures became effective. Even though local eradication in known infested areas might be accomplished, it would always be reasonable to fear that a mosquito which had crossed the 1,600 mile expanse of the South Atlantic might have spread during the nine years it had been present in America many hundreds of miles to regions where it had not yet been recognized. Many would question the expenditure of large sums of money to eradicate gambiae from Brazil while inexhaustible supplies of the species in Africa constituted a permanent threat of reinfestation.[11]

The Malaria Service of the Northeast began operations after the rainy season of 1939 had set in, without a definite plan as to how gambiae could be controlled, although it was known that Paris

[11]The reality of this threat was revealed by the capture on October 9, 1941, of a female *Anopheles* (*Myzomyia*) *gambiae* on a flying boat at Natal at the end of a 21 hour flight from Lagos, Nigeria, West Africa, during the routine inspection and desinsectization which are carried out on all transatlantic planes on arrival in Brazil.

green had given good results as a larvicide for this species and that gambiae-transmitted malaria had been controlled in Zululand by the use of pyrethrum insecticide spray (Park Ross, 1936).

The first six months' work was very discouraging in spite of the fact that the funds allotted for this period were overspent. Malaria was rife on all sides and gambiae paid little heed to the ineffectual efforts of hundreds of untrained men but proceeded up the Jaguaribe and its tributaries apparently unrestrained (see Map Page 24). An appeal for additional funds brought a generous response from the Brazilian Government of an additional five thousand contos ($250,000.00 U.S.) for the year; simplified methods of applying Paris green, both wet and dry, were adopted; anti-larval work was reinforced by pyrethrum spray desinsectization; the hand capture of adult gambiae as an independent check on the distribution of the species was replaced by the flit-umbrella method (Barber and Rice, 1938); the intensive training of carefully selected men eventually gave visible results; and before the end of the year gambiae had apparently been eradicated from certain districts and its dissemination successfully blocked at most points.

The first year's work ended on an optimistic note, quite different from that emitted at the end of the first half year; it was felt that the demonstration of local eradication with available materials and technique had been made and that the problems still to be solved were largely of an administrative character. Arrangements were made for adequate funds (twelve thousand, five hundred contos or $625,000.00 U.S.) for the first six months of 1940, and a staff sufficient to cover the infested area was developed, eventually reaching a total of four thousand men.

Even under these favorable circumstances the most optimistic observers failed to foresee the rapidity of gambiae's retraction during the second year's campaign. To the surprise of everyone, the area in which gambiae infestation could be found continued to diminish right through the rainy season, an unusually heavy one, at a time when exceptionally high densities were registered in two uncontrolled areas reserved for unhampered study of the biology of the species. Early in April (1940) it was decided to make the crucial test of the significance of negative findings, and all control measures were suspended in a previously heavily infested section of the Salgado River valley where the species had not been found during the first three months of the year. With the failure of gambiae to reappear in this area, it became routine practice to discontinue all control measures in a district after three months' failure to find the

species. Continued careful systematic observation of the Salgado valley over a period of 18 months (April 1940 to October 1941) has failed to reveal any recurrence of gambiae and in no case has this species reappeared in a district in which control measures were suspended on the basis of three months' negative findings.

Before the end of June it was apparent that gambiae would probably be eradicated within a few months and on September 7, Brazil's Independence Day, a staff luncheon of the Malaria Service of the Northeast, in Fortaleza, celebrated the new freedom of Brazil from the African invader. Some weeks after this celebration, an isolated pocket of gambiae infestation was found some 60 was intensively worked, with the result that the last evidence of infestation in Brazil to date was recorded on November 14, 1940, less than two years after the organization of the Malaria Service of the Northeast.

Since January 1941 all anti-gambiae measures in Brazil have been suspended, a cash reward has been offered for the finding of gambiae and a large staff of trained men have been kept searching for the species in the previously infested areas and throughout contiguous regions, with negative results. Provision is being made for continuing these activities of the Malaria Service of the Northeast as a cooperative project financed by the Brazilian Government and The Rockefeller Foundation, at least until the end of the 1942 rainy season. After this it is hoped that the responsibility for future checking and vigilance will be turned back to the regular health authorities, thus obviating the necessity for the continuation of a special service.

DISCUSSION

Many workers in the control of mosquito-borne disease have been more than reluctant to accept the idea that man has it in his power to eradicate any mosquito anywhere, no matter what the effort made. Psychologically it is apparently much easier to visualize the geometric increase of a species from a single gravid female to the millions of gambiae existing at one time in northeast Brazil than it is to picture the reverse process, as all possible breeding places in a region are treated week after week with Paris green and the highly domestic and extremely susceptible adult is subjected at frequent intervals to pyrethrum insecticide spray in the buildings of infested districts. The traditional ingrained philosophy that species eradication is impossible, that a species is something sacred and eternal in spite of the example of the dodo, the passenger pigeon and

the dinosaur to the contrary, and that when species disappear they do so only in response to "cosmic" or "biological" rather than man-made factors, is most persistent.

It is still too early to claim, on the basis of negative findings, that the last infestation of gambiae has disappeared from Brazil, but there can be no doubt that the failure of hundreds of well-trained searchers to find any trace of this mosquito, which is especially easy to find because of its larval and adult habits, many months after all control measures have been suspended,[12] is at least indicative of local eradication in many areas. Likewise, though large areas of Brazil are still infested with aegypti, it is a fact that this mosquito cannot now be found under favorable conditions in many cities and towns and even in entire states where it previously abounded.

Those who have followed the work in aegypti and gambiae in Brazil are convinced that local species eradication has been adequately demonstrated for both species; that the present program of the National Yellow Fever Service may well lead to the eradication of aegypti from Brazil and that a technique is available for the rapid elimination of any future gambiae infestation which may perchance be found in northeast Brazil.

In the face of these results, it is interesting to consider the possibility of extending species eradication of aegypti and of gambiae to other regions and of applying the same concept to other species of mosquitoes. The wide variety of difficult aegypti situations already solved in Brazil gives confidence regarding possibilities elsewhere, and it is believed that no insuperable difficulties will be encountered in applying eradication to this species wherever it exists. Anti-aegypti measures in Bolivia have already resulted in cleaning many previously infested areas. Going further afield, a most attractive problem would be the organization of an eradication program for aegypti in Egypt, the country from which it takes its name.

With regard to gambiae, it may be argued that the Brazilian experience proves nothing, since the species was outside of its normal habitat.[13] Those who saw gambiae in action in 1938-39 have no

[12]Since both Paris green and pyrethrum, the essential elements in the anti-gambiae campaign in Brazil are ephemeral in action, the suspension of control measures left conditions as favorable for gambiae proliferation as before the campaign. Draining and filling, considered so important in many malaria control projects, took no essential part in the eradication of gambiae.

[13]A prominent European malariologist writes:

"I learn with pleasure that the last larvae and adults of *A. gambiae* were seen in October of 1940 in northeastern Brazil. I believe that you will agree with me in holding that, if this be true, we must suppose that biological factors have intervened to cause this disappearance; this would not be surprising considering the fact that the anopheline is of recent immigration."

doubts but that this species, unchecked, would have spread to many parts of the Americas and succeeded in maintaining itself as successfully as has that other invader from the Old World, *Aedes aegypti.*

The senior author visited Africa in 1935 and saw many regions, from Zululand in the South, to the Anglo-Egyptian Sudan to the North, where gambiae-transmitted malaria is a serious problem. On the basis of Brazilian results he believes that some of these can be cleared of gambiae at a reasonable cost with the same methods and then protected against reinfestation with relative ease.

With regard to eradication of other species, no conclusions should be drawn previous to a careful study of all factors involved, followed by even more careful work and observation in the field. The U. S. Department of Agriculture, in spite of its success in the eradication of the Mediterranean fruit-fly, has not undertaken the complete elimination of the Japanese beetle, and the Brazilian National Yellow Fever Service, which has embarked on a program of aegypti eradication, has not considered undertaking similar projects against those species responsible for the transmission of jungle yellow fever.

Among the factors which make species eradication feasible, are:

1. Ease in discovering both aquatic and adult forms.
2. Efficiency of methods of destroying or sterilizing, permanently or temporarily, all breeding places.
3. Opportunity to eradicate the species in a sufficiently large or isolated geographical area so that the periphery, subject to reinfestation from dirty unworked areas, represents but a small fraction of the area worked.
4. Demonstrated public health and economic importance of species to be eradicated. Men, money, time and full authority are needed for carrying out species eradication and these are generally available in adequate quantity only for truly serious problems.

Using these criteria there are undoubtedly a great many problems which can be solved by species eradication at much lower cost *in the long run* than by any other method.

One reads, for example, of the loss of 100,000 lives and the expenditure of £350,000 in a single great epidemic of malaria in the island of Ceylon and wonders what the immediate cost and ultimate advantages might be of eradicating *A. culicifacies* from the

island and thereafter maintaining a sentinel service to prevent reinfestation from the mainland.

One sees the short narrow irrigated river valleys of the Pacific slope of Peru, isolated from the rest of the world by the high Andes to the east and the Pacific Ocean to the west, and from each other by long stretches of absolute desert, under the heavy economic handicap of annual outbreaks of malaria coinciding with the busy harvest season, and realizes that here is an ideal physical setting (Shannon 1930) in which to attempt the piecemeal eradication of *A. pseudopunctipennis,* the only vector of the region, from one valley after another.

The advantages of attacking problems having definite limits are so great that attempts at species eradication in the immediate future may well be limited to such geographical areas as present important obstacles to reinfestation, both during the campaign and after eradication has been accomplished. In addition to the problems already cited, the many malarious islands of the world, including those in the Caribbean region, would seem to offer a challenge to the responsible public health authorities. On the other hand, it must be remembered that the species eradication technique was developed in Brazil in the absence of any natural obstacles to widespread dissemination of aegypti.

It is not the purpose of this paper to give the impression that species eradication is easy and simple. Final results can be disappointingly slow with a species such as aegypti, the ova of which may be viable for a year or more and are not infrequently transported from place to place by travellers; or gratifyingly rapid, with a species like gambiae which has no such means of defense and is so highly domestic that it can be easily attacked in the adult as well as in the larval form. But in each instance, success is attained only on the basis of careful organization and meticulous administration. It is not sufficient to plan the program and give orders for its execution; it is essential that there be careful independent checking of results.

Each species will present different problems which must be met by altered methods. For example, eradication of aegypti has proceeded from the larger cities to the tributary areas but in the attempt to eradicate gambiae special emphasis was placed on its elimination first from the peripheral zone of the infested area, since it was here that expansion was occurring.

It must be remembered that failure to find a species during a short period should not be interpreted as an indication that eradica-

tion has been accomplished; only after all control measures have been suspended and free opportunity given for multiplication of the species, do negative findings become significant. A case in point is the experience at Durazzo, Albania (Hackett *et al,* 1938): in the third year after the salinification of the only breeding place of *Anopheles maculipennis* var. *elutus* which could be found for miles around, not one of this species was found in eight scattered catching stations visited weekly during an entire summer, but in the following year, the silting up of the outlet canal produced an area of relatively fresh water, with the result that by the middle of the summer heavy production of elutus was again apparent. Here, negative findings did not stand the test of even temporary interruption of control measures.

SUMMARY

Species eradication has been successfully demonstrated as a practical method of handling the problems of *Aedes aegypti* and *Anopheles gambiae* in Brazil. The suggestion is made that eradication may be equally feasible for these two species in other countries and even for some other species under certain conditions.

BIBLIOGRAPHY

Barber, M. A. and J. B. Rice. Malaria in Poona and in its vicinity. Jl. Mal. Inst. India, *1:* 37-55, 1938.

Carter, H. R. The early history of yellow fever. Williams & Wilkins, Baltimore, 1931.

Cruz, Oswaldo Goncalves. Prophylaxis of malaria in Central and Southern Brazil, in Ross, The Prevention of Malaria, E. P. Dutton & Co., N. Y., 1910.

Gorgas, W. C. Malaria prevention on the Isthmus of Panama, in Ross, The Prevention of Malaria, E. P. Dutton & Co., N. Y., 1910.

Hackett, L. W., P. F. Russell, J. W. Scharff and R. Senior White. The present use of naturalistic measures in the control of malaria. Quart. Bull. Health Organ. League of Nat., 7: 1016-1064, 1938.

Park Ross, G. A. Insecticide as a major measure in control of malaria. Quart. Bull. Health Organ. League of Nat., 5: 114-132, 1936.

Reed, Walter, James Carroll, A. Agramonte and Jesse W. Lazear. The etiology of yellow fever. Proc. 28th Ann. Meeting Am. Publ. Health Ass'n, Oct. 22, 1900.

Ross, Ronald. Preliminary report on the infection of birds with proteosoma by the bites of mosquitoes. Oct. 11, 1898. Gov't Press, Calcutta.

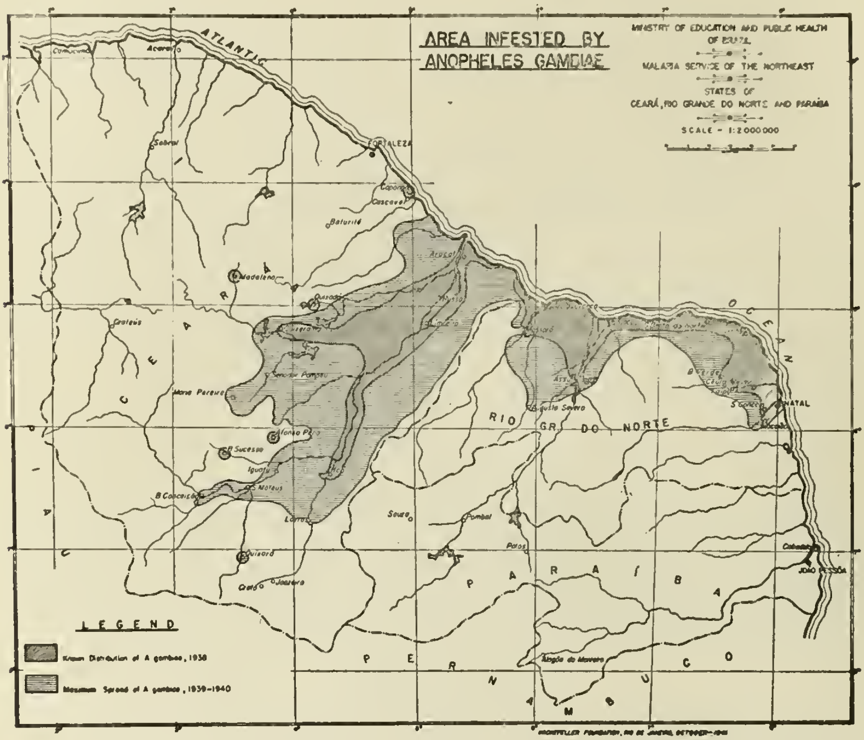
Shannon, R. C. and G. C. Andrade. Dry season observations of the African mosquito, *Anopheles gambiae,* in Brazil in 1938. Am. Jl. Trop. Med., *20:* 641-668, 1940.

Shannon, R. C., Observations on *Anopheles pseudopunctipennis* in Peru. American Journal of Hygiene, Vol. XII, No. 2, Pages 442-448, September, 1930.

Soper, Fred L. Present day methods for the study and control of yellow fever. Am. Jl. Trop. Med., *17:* 655-676, 1937.

Strong, L. A. Report of the Plant Quarantine and Control Administration, Fiscal year ending June 30, 1931. Dep't. Agriculture, Washington, D. C.

Watson, Malcolm. The Prevention of Malaria in the Federated Malay States. Liverpool School of Tropical Medicine, 1911.


AREA INFESTED BY ANOPHELES GAMBIAE
MINISTRY OF EDUCATION AND PUBLIC HEALTH OF BRAZIL
MALARIA SERVICE OF THE NORTHEAST
STATES OF CEARÁ, RIO GRANDE DO NORTE AND PARAÍBA
SCALE - 1:2000000
ATLANTIC
OCEAN
FORTALEZA
Baturité
Sobral
Aracati
Russas
Limoeiro
Quixadá
Senador Pompeu
Crateús
Iguatu
Lavras
Quixará
Crato
Joazeiro
Souza
Pombal
Patos
Mossoró
Assú
Augusto Severo
NATAL
Cabedelo
JOÃO PESSÔA
C E A R Á
RIO GR. DO NORTE
P A R A Í B A
P E R N A M B U C O
LEGEND
Known Distribution of A. gambiae, 1938
Maximum Spread of A. gambiae, 1939-1940

ANOPHELINES OF SOUTHWESTERN YUNNAN AND THEIR RELATION TO MALARIA*

W. C. Sweet, L. C. Feng, C. Y. Chow, and S. C. Hsu
(Received for Publication December 1, 1941)

Malaria in the Yunnan Province of China has an ancient and dishonorable history. Existing written records describe the disease and its effects from as far back as about 1,700 years ago. That it now is of international importance is indicated by the history of the Yunnan-Burma Highway, by the appointment from the United States Public Health Service in 1940 of a commission to study the situation, and the more recent selection by the United States Government of a large health and medical commission to work in the region of the proposed Yunnan-Burma Railway. Just recently the tarring of the southern end of the China side of the highway was so much slowed down by attacks of malaria in the labor force that the work could not be completed before the rainy season set in.

In spite of the long history of the disease known as chang ch'i, it was only a few years ago that this was shown to be malaria by Ling, Liu, and Yao (1), and that Yao and Ling (2) published an account of the anopheline fauna of Southwestern China with some reference to its relation to malaria. More recently Robertson published (3 and 4) two papers about the malaria along the highway, and Williams (5) gave a presidential address on the same subject before the American Society of Tropical Medicine.

Considering the severity of the malaria problem at the southern end of the Yunnan-Burma Highway, the International Health Division of The Rockefeler Foundation established a laboratory for the study of the malaria problem at Chefang, Yunnan Province, in March 1940 in a building then in temporary use by the United States Public Health Service Malaria Commission headed by L. L. Williams. This report will give certain results of the work done by the laboratory group organized at that time.

---

*Read before a joint session of the American Society of Tropical Medicine and the National Malaria Society at a meeting of the Southern Medical Association, St. Louis, November 13, 1941.

The work here reported was done in cooperation with the National Health Administration of China by the International Health Division of The Rockefeller Foundation.

Description of Area

Chefang, a village on the Yunnan-Burma Highway of about 2,500 population, is the headquarters of a Shan State under Chinese sovereignty, which extends for a considerable distance along the Burma border and for some 20 to 30 miles into China. Many parts of the Sino-Burmese border line in this area are still undefined, some parts are as yet unexplored, and others are in the hands of wild tribes with whom there is no communication without army protection. The town is about 24.0° north and 97.6° east, is some 92 miles north of the Tropic of Cancer, and has an altitude of about 2,700 feet above sea level. Until the opening of the highway the Chinese population was small and the authority of their government was weak; but since then there has, of course, been a large influx of Chinese laborers, soldiers, and officials, with a growing tendency for the central and provincial governments to assume more power.

The village of Chefang lies near the northern end of a hill-encircled valley some 20 miles long and from 5 to 10 miles wide, with many small side valleys between the hills. The population in the valley of approximately 25,000 is still mainly Shan, with villages of Kachins, Li-ssu, and other tribes on the surrounding hills. The work here reported was confined to this valley, which was considered typical of most of southern and western Yunnan. The Shans are a pastoral and agricultural people whose chief product is rice, one crop of which is grown between May and November under irrigation by numerous channels taken off from the many small streams flowing into the central river of the valley. This river flows into the Shweli, a tributary of the Irrawaddy, at the southern end of the valley.

At the time of writing this report temperature and relative humidity data were available for fourteen months, but rainfall had been registered for ten months only. Fahrenheit temperatures were taken on a covered porch on the east side of the laboratory courtyard. For the period in which records were available, from May 1940 through June 1941, the extremes of temperature were 102.2° in May 1940 and 43.0° in February 1941; mean monthly maxima varied between 92.1° in May 1941 and 77.2° in January 1941, while mean minima were between 73.5° in July 1940 and 44.6 in January 1941. Relative humidity percentages at 8:30 a. m. varied between 100 and 92 (April 1941) for maxima, and between 84 and 43 (February 1941) for minima; corresponding figures for 4:30 p. m. were 100 and 61, with 56 and 16 for lowest percentages.

This part of Yunnan has a definite rainy season extending from May through October, and it seems probable from present records that the average annual rainfall will be between 50 and 60 inches. In March 1941 there was rain on only three days, with a total of 0.14 inches, while in June 1941 there was rain every day in the month, with a total of 17.54 inches, the greatest fall in 24 hours being 2.19 inches.

The Anophelines

In a critical review of the distribution of mosquitoes in China, Feng (6) in 1939 listed fourteen species of anophelines and two varieties of *hyrcanus* as having been reported from the Province of Yunnan. Robertson (3 and 4) added three species to this list, and Yao and Pei (7) mention, with reservations, the finding of *A. fluviatilis*. During the work in the Chefang Valley twenty-one species or varieties of anophelines have been identified, of which *A. aconitus, A. anandalei* var. *interruptus, A. leucosphyrus, A. subpictus,* and *A. stephensi* seem to be newly reported for Yunnan and all but *subpictus* new for all China. It was not possible to determine whether the *stephensi* were of the type form or of the variety mysorensis of Sweet and Rao (8). The anophelines identified were as follows:

A. aconitus
A. aitkeni
A. anandalei
  var. *interruptus*
A. annularis
A. barbirostris
A. culicifacies
A. fluviatilis
A. gigas
  var. *baileyi*
A. hyrcanus
  var. *sinensis*
A. hyrcanus
  var. *nigerrimus*
A. jeyporiensis
  var. *candidiensis*
A. kochi
A. leucosphyrus
A. lindesayi
A. maculatus
A. minimus
A. splendidus
A. subpictus
A. stephensi
A. tessellatus
A. vagus

We have the same reservations in regard to the presence of *A. fluviatilis* as were mentioned by Yao and Pei (7); gradations between mosquitoes surely identified as *A. minimus* and those probably *fluviatilis* are so numerous that it is not possible as yet to be positive, although dissections of 180 mosquitoes identified as *fluvi-*

atilis yielded no malaria infections, in contrast to dissection results in undoubted *A. minimus.*

Dissections of Anophelines

Reports of results of dissections of anopheline mosquitoes in Yunnan are few, the earliest seeming to be one by Gaschen in 1935 (9), who reported finding one infected *A. culicifacies* in eastern Yunnan, without giving the number dissected. Yao and Ling in 1937 (2) reported dissecting 85 *A. minimus* and finding four infected with oocysts, 4.7 per cent; they also found one specimen with oocysts out of 53 *A. jeyporiensis* var. *candidiensis* dissected, 1.9 per cent; and no infections in nine *A. hyrcanus* var. *sinensis.* Robertson (4) reported 1,387 dissections of anophelines with the finding of 31 specimens with oocysts, 20 with sporozoites, and eight with both stomach and salivary glands infected in seven of the nine species represented. Species and infection rates were as follows: *annularis,* 1.5; *minimus,* 9.7; *sinensis,* 2.6; *candidiensis,* 5.6; *culicifacies,* 3.8; *maculatus,* 3.0. From the same valley in which Robertson worked, Yao and Pei (7) report dissections of twelve species with the finding of one female with oocysts in 1,695 *A. hyrcanus* var. *sinensis* dissected, 0.06 per cent, and three in 1,363 *A. jeyporiensis* var. *candidiensis* examined, 0.2 per cent; the infection rate in 5,883 *A. minimus* was 3.3 per cent. The Chefang Valley is the next one to the south on the Burma Highway from the Mangshih Valley from which the last two reports came, and the two villages are about 22 miles apart.

During a period covering sixteen months in the Chefang Valley, 26,372 female anophelines of thirteen species were dissected with the finding of malaria infections in one species only, *A. minimus.* The numbers of other species dissected are given in Table 1.

Table 1. Anopheline Dissections in the Chefang Valley, not Including *A. minimus* No Malaria Infections Found

SPECIES	NUMBER DISSECTED	SPECIES	NUMBER DISSECTED
A. hyrcanus var. *sinensis*	6,152	*A. vagus*	130
A culicifacies	471	*A. subpictus*	99
A. maculatus	288	*A. splendidus*	22
A. fluviatilis	180	*A. aconitus*	18
A. jeyporiensis var. *candidiensis*	158	*A. tessellatus*	11
A. annularis	135	*A. gigas* var. *baileyi*	1

As compared with the report of Yao and Pei (7), the relative scarcity of *A. jeyporiensis* var. *candidiensis* in the Chefang Valley catches is striking. *A minimus* was by far the most common mosquito in both valleys, in the houses and stables used for catching stations, with *A. hyrcanus* var. *sinensis* about one-third as abundant in both places.

There were found 127 mosquitoes with oocysts on the stomach, 54 with sporozoites in the salivary glands, in a total of 164 *A. minimus* infected out of 18,707 dissected, 0.9 per cent. Monthly mosquito infection rates for the valley as a whole varied from zero in December, January, and February, to 1.6 per cent in September, so there would seem to be a definite off-season for malaria in this part of Yunnan of at least two months. The numbers of *A. minimus* are lowest in these three months; they increase in March, April, and May depending on the rainfall, decrease somewhat during the heavier rains of June and July, and then increase again to reach a peak in October.

Table 2. Results of *A. minimus* Dissections in the Chefang Valley

Month	Number Dissected	Number With Oocysts	Number With Sporozoites	Number of Mosquitoes Infected	Percentage of Mosquitoes Infected
1940					
March 20 to 31	112	0	0	0	0.0
April	247	0	1	1	0.4
May	968	4	3	7	0.7
June	1,366	2	4	5	0.4
July	1,491	6	5	10	0.7
August	1,692	18	9	24	1.4
September	1,910	29	8	31	1.6
October	2,162	24	6	28	1.3
November	1,714	18	4	21	1.2
December	664	0	0	0	0.0
1941					
January	389	0	0	0	0.0
February	642	0	0	0	0.0
March	1,208	8	0	8	0.7
April	1,987	5	7	10	0.5
May	1,107	6	4	10	0.9
June	1,048	7	3	9	0.9
All months	18,707	127	54	164	0.9

In Table 3 the *A. minimus* caught are classified as to whether they were in Chefang or the surrounding villages. Of 14,187 *A. minimus* caught in the smaller outlying villages, 86 were found infected on dissection, 0.6 per cent; whereas the corresponding rate for Chefang-caught *minimus* was 78 infected out of 4,520 dissected,

1.7 per cent. It is to be remembered that the majority of the incoming, more susceptible Chinese lived in Chefang.

Table 3. Results of *A. minimus* Dissections According to Place of Catching

Mosquitoes Caught in	Surrounding Villages			In Chefang			Total		
	in Houses	in Stables	Total	in Houses	in Stables	Total	in Houses	in Stables	Total
Number Dissected	9,551	4,636	14,187	3,305	1,215	4,520	12,856	5,881	18,707
Number Infected	67	19	86	65	13	78	132	32	164
Per cent Infected	0.7	0.4	0.6	2.0	1.1	1.7	1.0	0.5	0.9

For dissection purposes all available resting anophelines were caught during the day in structures, in Chefang and the surrounding villages, which could be roughly classified as houses for human habitation and stables in which the most common animals were pigs, cows, buffaloes, chickens, dogs, and horses. Owing to local habits in building, the division was in most cases artificial, the stable being either across the courtyard from the living quarters or beneath them; but the results of such a classification seem of interest nevertheless. The *minimus* infection rate for the valley as a whole was 0.5 per cent for mosquitoes caught in structures classed as stables and 1.0 per cent for those caught in houses. This relationship was approximately the same in Chefang and in the surrounding villages.

Habits of A. minimus

Although tests for the source of *A. minimus* blood meals were not possible, the results of the catches of this species give some indication of its habits. The numbers of *minimus* caught in houses and stables indicate, to say the least, that it has no objections to such structures as daytime resting places, in contrast to its variety *flavirostris* in the Philippines. This trait would be of assistance in efforts to control the malaria in this area by measures directed against the adult mosquito.

Further, as is shown by Table 4, *A minimus* seems definitely to prefer structures classed as human habitations for resting places, which seems to indicate that it prefers human blood for its meals. This is more or less substantiated by one series of tests of blood meals of this species, (the exact reference is not available to the writer), made in neighboring Assam some years ago. Of all the

Table 4. Daytime Resting Places of Anophelines as Indicated by Catches for Dissections

Species	Total Number Dissected	Number Caught in Houses	Per Cent Caught in Houses
A. minimus	18,707	12,586	68.7
A. hyrcanus var. *sinensis*	6,152	992	16.1
Other species	1,513	846	55.9
All species	26,372	14,694	55.7

anophelines caught in Chefang Valley, 55.7 per cent were caught in buildings classed as human habitations. The greatest contrast was between the 68.7 per cent of *A. minimus* caught in houses, as against the 16.1 per cent of *A. hyrcanus* var. *sinensis* so caught; of the other species caught, 55.9 per cent were found in houses.

In our experience *A. minimus* is quite strictly limited in its choice of breeding places, larvae being rarely found in other places than ditches, irrigation channels, and streams with more or less swiftly moving fresh water; it is extremely rare in rice fields at any stage of the growth of the rice plants or any condition of the water in the fields. This fact will simplify a great deal any proposals for the control of breeding of this species.

From the results here reported for the Chefang Valley and from those reported by Yao and Pei (7) from the neighboring Mangshih Valley, it seems to be highly probable that *A. minimus* is the only anopheline of practical importance in the spread of malaria in southwestern Yunnan Province and that any proposals for the mosquito control of the severe malaria of this area need concern themselves with this species only.

Summary

1. A first report of temperature, humidity, and rainfall conditions in the Chefang Valley of Yunnan Province, China, was made.

2. A list of anopheline species found in the valley was made, including four species newly reported for China and one for Yunnan Province.

3. In 26,372 dissections of thirteen species of female anophelines caught in the valley, malaria infections were found in *A. minimus* only, this species having an infection rate for the whole valley and all sixteen months of 0.9 per cent. There seems to be no

malaria transmission in the months of January and February, at least, and the months of highest transmission extended from August through November, after the heaviest rains.

4. *A. minimus* uses houses and stables as daytime resting places, especially the former, and this may be an indication that it prefers human blood for meals.

5. *A. minimus* is almost entirely limited to more or less quickly moving, clean water in its breeding and is almost never found in rice fields.

6. Any proposals for the mosquito control of malaria in southwestern Yunnan, it seems highly probable, need consider the control of *A. minimus* only.

References

1. Ling, L. C., Liu, K. B., and Yao, Y. T., 1936. Studies on the So-called Chang Ch'i. Part II. Chang Ch'i in Yunnan. China Med. Jour., 50, 1815-1828.

2. Yao, Y. T., and Ling, L. C., 1937. Study of Mosquito Fauna in Southwestern China, Especially in Provinces of Kweichow and Yunnan. Part I. Tribe Anophelini. Jap. Jour. Exp. Med., 15, 121-136.

3. Robertson, R. C., 1940. Malaria in Western Yunnan with Reference to the China-Burma Highway. China Med. Jour., 57, 57-73.

4. Robertson, R. C., 1941. A Malaria Survey on the China-Burma Highway. Trans. Royal Soc. Trop. Med. and Hyg., 34, 311-332.

5. Williams, L. L., 1941. Malaria on the China-Burma Highway. Am. Jour. Trop. Med., 21, 1-11.

6. Feng, L. C., 1939. The Geographical Distribution of Mosquitoes in China. International Congress for Entomology, 1938, 7, 1579-1588.

7. Yao, Y. T., and Pei, Y. S., 1941. Some Epidemiological Factors of Malaria in Mangshih, Yunnan. To be published in China Med. Jour.

8. Sweet, W. C., and Rao, B. A., 1937. Races of *A. stephensi* Liston, 1901. Ind. Med. Gaz., 7, 665-674.

9. Gaschen, H., 1935. Faune entomologique des voies d'accès au Yunnan. Bull. Soc. Path. Exot., 28, 194-198.

OBSERVATIONS ON MALARIA AROUND LAKE WILSON, 1934-1941*

ROBERT BRIGGS WATSON, HELEN C. MAHER,
AND MARGARET E. RICE

Lake Wilson, the smallest and second oldest of the Tennessee River impounded water projects, was impounded in 1924 on the completion of Wilson Dam. It extends 16 miles to Wheeler Dam, and has 135 miles of shoreline. The main body of the lake is deep and wide, and the shoreline is precipitous. Before impoundage, this portion of the river formed a part of the Muscle Shoals, falling nearly 100 feet in 16 miles between towering limestone bluffs which now form the lake margins.

The only shallow water in Lake Wilson is over the flood plains of small tributary streams, which were impounded with the river; and in small indentations which occur along the main shoreline. In these locations there has been a progressive invasion of aquatic plants, principally water willow weed (*Dianthera americana*) and alligator grass (*Achyranthes philoxeroides*). The latter plant is not native to the Tennessee Valley and was first observed in Lake Wilson in 1936, since when it has spread rapidly in the lake and elsewhere, tending to replace other plants.

For purposes of comparative malaria studies, we have found it convenient to classify impounded waters roughly according to their propensity to produce *Anopheles quadrimaculatus.**

Most of Lake Wilson is composed of Type III areas, there are no Type I situations, and it is possible to control mosquito propagation effectively by manipulation of the pool level. During the eight years' period under discussion, anophelism in the mile-zone around the lake has been kept at a relatively low level as compared with other Tennessee River lakes. There have been occasional periods of prolific propagation when summer floods or other causes

---

*From the Health and Safety Department, Tennessee Valley Authority, Wilson Dam, Alabama. The studies upon which this report is based were made in cooperation with the Alabama State Department of Public Health.

*This classification provides for three "Area Types" as follows: Type I; situations which approach or attain the optimum requirements for the propagation of *Anopheles quadrimaculatus*. Production of mosquitoes is prolific and is difficult or impossible to control. Type II; situations characterized by moderate or prolific mosquito production which can be controlled by antilarval measures. Type III; situations which do not produce mosquitoes ordinarily, or where propagation is intermittent or slight, and control is effected easily.

prevented pool level fluctuation. There has also been a practically irreducible minimum of mosquito production in a few situations.

For practical purposes anophelism in the Lake Wilson mile-zone may be attributed almost entirely to mosquito propagation in the lake. There are no natural breeding places within several miles of the lake on the north side. On the south side there are a few small natural ponds from which mosquitoes might conceivably fly into the mile-zone. Save for the year 1935 when the lake was operated, in effect, as a constant level pool, anophelism has been maintained at a fairly low level on a seasonal basis.

The population of the mile-zone is entirely rural and predominantly white. As compared with other sections of the Tennessee Valley, it is relatively fixed in the sense that there is less tendency for families to move annually. The population density is low, averaging about 27 people per mile of shoreline in the mile-zone. There are two small communities, one of 340 people near the lake, the other of 430 at the periphery of the mile-zone. Housing is perhaps slightly better than the average for northern Alabama, but is poor when compared with academic standards for good rural housing. Mosquito-proofing of houses is exceptional.

Prior to 1934, when the malaria control program of the Authority was begun, there are no precise data on malaria prevalence in this region. The lake was impounded in the summer of 1924. Prolific propagation of *A. quadrimaculatus* ensued, and the rate of malaria transmission was evidently raised considerably above normal levels as a consequence. In the light of all that is known and taught about *A. quadrimaculatus* propagation, and of the factors concerned in malaria transmission, no other conclusion can be made. During August 1924 the Alabama State Department of Public Health, in cooperation with the United States Public Health Service and the International Health Board of the Rockefeller Foundation, undertook an investigation of malaria prevalence near the lake. The area surveyed was approximately the same as that designated in this discussion as the mile zone.

The reports* of this investigation are fragmentary. In Colbert County, south of Muscle Shoals, 1,038 persons in 189 families were visited. Of the blood films examined, 10.7 per cent were positive for malaria parasites. In Lauderdale County, north of Muscle Shoals, 554 individuals in 101 families were visited, but no blood film survey data are given. History of malaria at some time during

*Records in the files of the Alabama State Department of Public Health.

the five years preceding 1924 was elicited from about 50 per cent of the persons questioned.

In September 1933 the Alabama State Department of Public Health made a malaria survey of 43 families selected at random in the mile-zone of Lake Wilson. Of 206 blood films collected, 20 per cent were positive for malaria parasites, of which 57 per cent were positive for *Plasmodium falciparum.*

Since 1934 the population of the mile-zone around Lake Wilson has been surveyed annually to determine the prevalence of malaria. The field work has been done during October and November, except in 1934 when the survey was made in late August and early September. The time selected was determined in part by convenience, and in part by the fact that at an earlier date families

Table 1
Distribution of Malaria Survey Samples by Sex and Race, Lake Wilson, 1934-1941

Year	Total Blood Films	Percentage Distribution of Samples			
		White		Negro	
		Male	Female	Male	Female
1934	1,694	35.0	47.0	8.4	9.6
1935	573	30.0	42.7	11.9	15.4
1936	580	29.6	42.6	12.4	15.4
1937	1,447	33.7	40.9	11.7	13.7
1938	827	24.2	48.8	16.0	11.0
1939	805	30.4	45.6	10.6	13.4
1940	1,655	30.6	43.9	11.6	13.9
1941	1,563	29.3	41.5	12.1	17.1
Total	9,144	31.1	44.0	11.0	13.9

are away from home during the day gathering crops. The technique employed in making blood film surveys has been the same each year. Thick and thin blood films were collected on the same slide, stained by the Giemsa technique, and examined in the same laboratory.

Composition of Survey Samples

Table 1 shows the composition of the survey samples by sex and race. The size of the samples has varied considerably. This is a reflection of the amount of time and personnel available for field work. The primary purpose of the surveys was to appraise the efficiency of control operations; therefore, endemic foci were sought out consciously when more complete surveys could not be made. A consistent effort was made to survey adequately all individuals associated with the most prolific sources of mosquito propagation.

The total population of the mile-zone, about 4,800, has not varied greatly during the eight years' period; therefore, the range of the annual samples has been between 12 and 34 per cent of the total population. Since the surveys have tended to be selective as noted, an element of bias in favor of high parasitemia rates has been introduced.

For the entire period, 75 per cent of the blood films were secured from white individuals, with an annual range of 71 to 82 per cent. The annual range of the negro portion of the total samples was 18 to 29 per cent, with an average for the period of 25 per cent. Thus, there was considerable uniformity of sampling so far as race is concerned.

In the eight years, 42 per cent of total films taken were from males, with a range of 40 to 45 percent. The range for films from females was 55 to 60 per cent.

The four years, 1934, 1937, 1940, and 1941 contributed 70 per cent of all fims taken in the eight years. In these years the sex distribution was more nearly equal. In 1937 an effort was made to secure equal numbers of males and females. The resultant 45 per cent for males represents in all probability as even a distribution by sex as it is practically possible to obtain in surveys of this kind and for this rural population.

It can be noted from Table 3 that the excess of females in the total samples, while consistent, was contributed principally by the age group 20 to 39 years. In this age group it is logical to expect to find more females than males in the homes during the day.

Observations on Malaria Incidence

Geographic Location of Malaria Cases

It has been noted elsewhere (Smith, Watson and Crowell, 1941) that most of the malaria cases around Lake Wilson are associated with tributary streams; and that prevalence diminishes directly with distance from the lake. The latter circumstance is substantiated by the data in tables 2 and 2a. The persons who lived in area type II within a quarter of a mile from the reservoir showed a prevalence of 6.19 per cent; those between a quarter and a half mile, 5.01 per cent; those between a half and three-quarters of a mile, 3.29 per cent; and 2.09 per cent of the persons living between three-quarters and a mile from the reservoir were found to be positive for parasites. In the type III areas, the prevalence in the quarter mile

zone was 7.22 per cent; in the quarter to half mile area, 2.04 per cent; in the half to three-quarters mile area, 1.52 per cent; and in the three-quarters to one mile area, 1.27 per cent. In general, more malaria was found associated with type II than with type III areas.

Table 2

Prevalence of Malaria Around Lake Wilson, 1934-1941, by Distance from the Lake, Race and Area Type

Distance from Lake	Race	Type 11 Areas		Type III Areas		Difference	
		No. films	% pos.	No. films	% pos.	Per cent	Std. dev.
Zone 1	White	989	6.37	513	5.26	1.11*	1.255
0-¼ mi.	Negro	385	5.71	96	17.71	12.00	4.072
	Total	1374	6.19	609	7.22	1.03*	1.234
Zone 2	White	1213	4.78	1421	2.04	2.74	0.718
¼-½ mi.	Negro	603	5.47	487	2.05	3.42	1.126
	Total	1816	5.01	1908	2.04	2.97	0.606
Zone 3	White	493	2.84	753	1.46	1.38*	0.866
½-¾ mi.	Negro	298	4.03	167	1.80	2.23*	1.535
	Total	791	3.29	920	1.52	1.77	0.752
Zone 4	White	604	2.48	782	1.02	1.46	0.728
¾-1 mi.	Negro	115	–	84	3.57	3.57*	–
	Total	719	2.09	866	1.27	0.82*	0.655
Entire	White	3299	4.55	3469	2.16	2.39	0.439
Mile	Negro	1401	4.78	834	3.96	0.82*	0.884
Zone	Total	4700	4.62	4303	2.51	2.11	0.388

Table 2a

Distance from Lake	Type II Areas		Type III Areas		Both Areas	
	Diff.	St. Dev.	Diff.	St. Dev.	Diff.	St. Dev.
Zone 1–Zone 2	1.18*	0.827	5.18	1.098	3.02	0.630
Zone 2–Zone 3	1.72	0.815	0.52*	0.517	1.15	0.473
Zone 3–Zone 4	1.20*	0.828	0.25*	0.555	0.70*	0.485

* Not significant

Note: Incompete records on some persons prevented accurate location of their residences and these individuals are omitted from tables 2 and 2a.

Few of the differences between zones are statistically significant* but the decline was evidenced by both races.

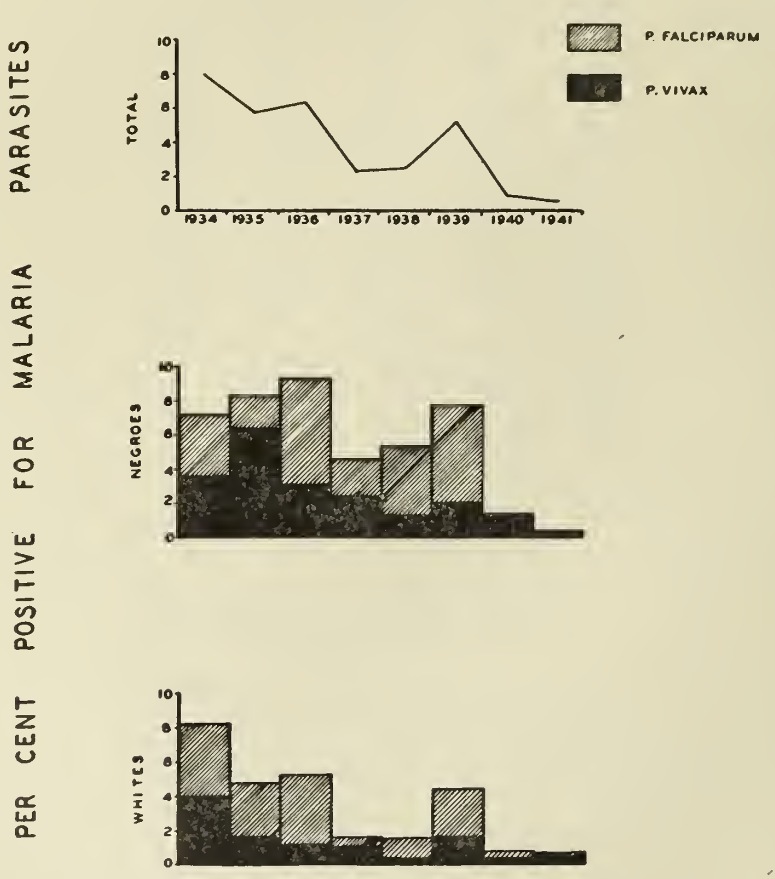
With regard to geographical distribution of parasite species, there is no significant concentration of either *P. vivax* or *P. falciparum* by zone in either race. The diminution in prevalence of each species varied directly with distance from the lake.

*The method used for determining significance throughout this study was by computation of standard deviations. Differences greater than two standard deviations are considered to be significant.

General Trend of Malaria Endemicity

The trend of malaria incidence around Lake Wilson should be considered in relation to the epidemic cycle of the disease in North Alabama. Our observations and the records of the Alabama State Department of Public Health indicate that the year 1934 was one of unusual malaria prevalence, probably an "epidemic year."

FIGURE I



MALARIA PREVALENCE RATES

LAKE WILSON 1934-41

Futhermore, from these data it appears that the years 1923 nd 1929 were epidemic years also. Therefore, it would seem logical to expect an unusual increment of malaria in North Alabama every 4 to 6 years; and it was believed that the year 1939 and subsequent years would supply evidence to support this inference.

Figure 1 indicates a trend of diminishing malaria incidence in the total population around Lake Wilson from 1934 to 1937. The transitory increase in 1936 as compared with 1935 is not significant statistically, but cannot be considered as entirely fortuitous, as will be shown later. The increase in incidence which began in 1938 was sustained and accelerated in 1939, and was followed by a sharp drop in 1940.

The Malaria Experience with Respect to Certain Variables

1. *Race* (Figure 1, Tables 3 and 4)

While the general trend of endemicity apparently conforms to preconceived notions of the epidemic cycle of malaria in North Alabama, it is not accurately descriptive of malaria prevalence in the two racial groups which form the population under consideration. Figure 1 and table 4 indicate that there was a consistent racial dif-

Table 3

Total Malaria Prevalence by Age, Race and Sex, 1934-1941

	White						Negro						Total	
	Males		Females		Both Sexes		Males		Females		Both Sexes		Both Races	
Age Group	No. Films	% Pos	No. Films	% Pos	No. Films	% Pos	No. Films	% Pos	No. Films	% Pos	No. Films	% Pos	No. Films	% Pos
0-4	520	2.88	485	2.89	1005	2.89	164	5.49	140	4.29	304	4.93	1309	3.36
5-9	465	2.80	473	4.65	938	3.73	189	8.47	186	4.84	375	6.67	1313	4.57
0-9	985	2.84	958	3.76	1943	3.29	353	7.08	326	4.60	679	5.89	2622	3.97
10-19	615	6.02	737	3.53	1352	4.66	227	5.29	297	5.72	524	5.53	1876	4.90
20-39	613	4.73	1389	1.80	2002	2.70	182	6.04	346	2.60	528	3.79	2530	2.92
40 and over	617	3.89	933	2.14	1550	2.84	245	3.67	307	1.30	552	2.36	2102	2.71
All Ages*	2834	4.16	4025	2.66	6859	3.28	1009	5.65	1276	3.53	2285	4.46	9144	3.58

* Includes films of persons of undetermined ages.

ference in the level of parasitemia during the eight years' period of observation. It will be seen that the transitory increment of general prevalence in 1936 was due largely to an increase of malaria in the negro population, the continuation of a trend which had been sustained since 1934. The trend of incidence in the white population

conforms very closely to that of the total population as would be expected because of the predominance of white people in the sample. Both negroes and whites participated in the increase in prevalence in 1939, but both relatively and numerically the increase was greater for whites than for negroes.

In general, a consistently higher level of endemic infection was maintained among the negroes, and particularly is this true during the post-epidemic years. On an annual basis, only the difference observed in 1938 has statistical significance. However, save for 1934, where the rates were essentially the same, all differences approach significance and for the entire period the difference is significant (1.18±0.48). Moreover, there was an excess of endemicity among negro males as compared with white males, and among negro females as compared with white females.

Table 4

Malaria Indices by Race, Sex and Years, 1934-41, with Differences

Race	Sex	Per cent Positive for Malaria Parasites 1934	1935	1936	1937	1938	1939	1940	1941	Total
White	Male	10.62	5.23	8.14	2.05	2.00	3.67	1.19	0.66	4.16
	Female	6.41	4.49	3.24	1.18	1.24	4.90	0.41	0.62	2.66
	Both Sexes	8.21	4.80	5.25	1.57	1.49	4.41	0.73	0.63	3.28
Negro	Male	9.86	10.29	6.94	5.33	9.89	10.59	1.56	0.53	5.65
	Female	4.91	6.82	11.24	4.04	2.27	5.56	1.30	0.37	3.53
	Both Sexes	7.21	8.33	9.32	4.63	5.38	7.77	1.42	0.44	4.46
Differences in Total Rates	Males and Females	4.33	1.56	2.43	0.99	2.98	0.40	0.66	0.07	1.68
	Standard Deviation	1.37	2.01	2.11	0.81	1.32	1.60	0.47	0.39	0.41
	White and Negroes	1.00	3.53	4.07	3.06	3.89	3.36	0.69	0.19	1.18
	Standard Deviation	1.65	2.45	2.54	1.62	1.59	2.10	0.54	0.39	0.48

2. *Sex* (Table 4)

In general, the trend of prevalence in the two sexes was similar over the eight years. Males consistently exhibited a higher malaria rate than females, although in only two years (1934 and 1938) are the annual differences of significance. For the entire period, however, the endemicity among males is significantly greater than among females (1.68±0.41). This excess is evidenced among males in the annual samples, in most instances among negroes as well as whites. In 1936 in negroes, and 1939 in whites, the female rate exceeded the male rate.

3. *Age* (Tables 3 and 5)

In the total sample, the age group 10-19 appears to contribute

Table 5

Malaria Incidence by Race, Age, and Years, 1934-1941

Race	Age	Per cent Positive for Malaria Parasites 1934	1935	1936	1937	1938	1939	1940	1941
White	0- 9	7.96	2.96	6.32	1.36	1.18	5.45	0.60	1.44
	10-19	11.14	5.88	5.63	2.40	3.30	2.25	1.48	0.47
	20 and over	6.75	5.58	4.74	1.31	1.18	4.19	0.58	0.18
Negro	0- 9	7.22	12.73	13.04	7.69	9.59	5.08	1.89	0.00
	10-19	13.24	12.12	8.89	5.66	0.00	5.71	3.37	0.89
	20 and over	4.29	2.94	7.14	1.91	4.42	10.10	0.44	0.53
Both Races	0- 9	7.82	5.79	8.51	3.02	3.70	5.36	0.91	1.03
	10-19	11.48	7.63	6.90	3.37	2.36	3.23	2.05	0.62
	20 and over	6.31	4.91	5.26	1.44	1.99	5.69	0.55	0.27

significantly to the malaria experience of the population. The preponderance of infection in this age group is experienced by both races and both sexes.

In both races the males appear to provide a greater reservoir of infection than do females, especially in the adult age groups, 20 and over.

In both sexes negroes show a higher infection rate than do white persons, particularly among children, 0-9 years.

The numerical quality of the data scarcely justifies a greater refinement with regard to time distributions by age groups than that given in table 5. Even so, some of the rates shown are not stable. In any given year, in both races, the principal reservoir of infection appears to be in children and adolescents. This is true especially for negroes, where a relatively high level of parasitemia is maintained.

4. *Trend of Species Parasitism*

In considering the relative prevalence of infections due to *P. vivax* and *P. falciparum,* the following points should be kept in mind:

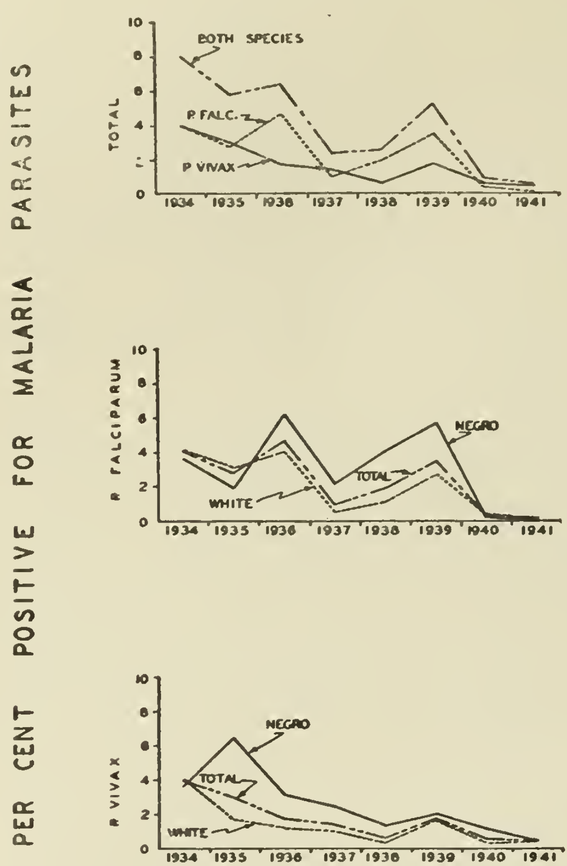
(a) The time of the surveys favored the presence of *P. falciparum* in blood films.

(b) At this latitude, it is generally believed that years of unusual malaria prevalence are characterized by relative increase of *P. falciparum* infections.

(c) In individual years, the numbers of films containing parasites are so small that strong inferences cannot be supported objectively.

From figure 2 it will be noted that the curve for total *falciparum* rates conforms more closely to the curve of total prevalence than does the curve for vivax rates. Rates for *falciparum* infections reached a

FIGURE 2



SPECIES PARASITEMIA RATES

LAKE WILSON 1934-41

low point in 1937; thereafter they rose through 1938 and 1939 and fell to their lowest value in 1941. These changes were experienced by both males and females and by both races. The highest values for *falciparum* infections were observed in 1936, following a decline in 1935.

From 1934 the trend of total *vivax* infections was downward

until 1938. This curve is apparently influenced principally by infections of whites, for there was a transitory increase of these infections in negroes in 1935. In both whites and negroes *vivax* infections increased in 1939 and declined to their lowest values in 1941.

Discussion

In view of the obvious weighting of the composite and annual samples by adult females, and because of the race, sex, and age differences in malaria prevalence observed, rates were adjusted for these variables. The rate differences obtained were insignificant.

There is no doubt but that in the year 1934 and 1939 more malaria was experienced by both races than in any two other years. The fall of malaria rates in 1940 and 1941, and the general decline of prevalence from 1934 to 1937, support the premise that the cycle of malaria prevalence in this region tends to be completed every fifth year.

The difference in the experience of negroes and whites seems to indicate that the general epidemiological picture of malaria in a given place is likely to be modified considerably by the racial composition of its population. As noted above, the difference in rates for negroes and whites in 1934 was only 1 per cent$\pm$1.654. The recorded excess was among the whites. In the post-epidemic years, 1935-1939, however, the experience is reversed; the negroes showing an excess of 3.58 per cent$\pm$0.879 over that of the whites.

This observation raises the question of the relative participation of the two races in an epidemic, and, conversely, the relative experience of the two races during interepidemic periods. It may be that the epidemic of malaria in this region occurs because of periodic excesses of prevalence among whites. This is suggested by the fact that the recorded experience of negroes in 1934, as compared with 1935 to 1939, is no greater than that which may be expected to occur by chance (0.66 per cent$\pm$1.658). For whites, on the other hand, the difference is 5.24 per cent$\pm$0.871, and the reduction followed almost immediately the peak of 1934.

Summary and Conclusions

A report is given of data collected from malaria surveys conducted in the autumn of each year from 1934 to 1941 from families living within one mile of Lake Wilson in North Alabama. Analyses of these data tend to confirm the premise that in this region cyclic

increases in malaria prevalence may be expected to occur every fifth year.

It is shown that a somewhat higher level of malaria prevalence occurred in males than in females regardless of race or age. In general, a higher level of prevalence was observed for negroes than for whites, both with regard to total infection and infection with *P. falciparum* or *P. vivax*. The total sample revealed a concentration of infection in the age group 10-19, and the annual samples indicated a preponderance of infections in children and adolescents. Prevalence in infection with both species of *Plasmodium* decreased directly with distance from the lake.

References

Smith, Gordon E., Robert Briggs Watson, and Robert L. Crowell, 1941. Observations on the flight range of *Anopheles quadrimaculatus*, Say. Amer. Jour. Hyg., 34(C):102-113.

THE CRUSHING STRENGTH OF BIOLOGICAL FILMS ON NATURAL WATERS AND THE SPREAD OF LARVICIDAL OILS*†

By Charles E. Renn

Graduate School of Engineering, Harvard University

When shallow pools, ponds, or other natural waters stand undisturbed by wind, waves, or rain, thin membranes of adsorbed and floating materials form upon their surfaces. For the greater part these thin coverings consist of bacteria, protozoa, algae, pollen, dusts, and microscopic debris imbedded in a tough, inelastic bacterial slime. The films vary greatly in biological composition, thickness, and area; the early stages of development are inapparent, but these thicken to form barely visible dusty or oil coatings. They are most readily seen when light breezes sweep them to the leeward margins of ponds, folding them into slimes and foams.

Aquatic biologists have given these surface supported films little attention, though they play a variety of significant roles in the economy of all shallow bodies of fresh water. In the discussion that follows only effects relating to practical mosquito control will be described. Generally speaking, surface supported films retard the spread of larvicidal oils and oil mixtures; under a variety of conditions they may render the oil ineffective.

Factors Determining the Spread of Larvicidal Oils:

Herms and Gray discuss the practical factors controlling the toxicity and spread of larvicidal oils in their recent text on anti-mosquito operations. (3) The current researches of Murray represent the most direct application of fundamental physical chemistry to the improvement of spreading properties. (4) For basic treatment of present concepts of the mechanisms of spreading in liquids, Burdon's brief monograph affords an excellent treatment. (2) All investigators working with larvicidal oils should read these references.

These researches were completed while the writer was in residence at the Station for Malaria Research in Tallahassee, Florida, during his tenure of a traveling fellowship from the International Health Division of the Rockefeller Foundation. The author wishes to acknowledge the encouragement and facilities given by Dr. Mark F. Boyd, Dr. John S. Elmdorf, Mr. Cornelius Kruse, Mr. Ralph S. Howard, and others.

†Contribution (000) from the Harvard Graduate School of Engineering.

In clean, uncoated waters, the ability of oils to spread over the water surface depends upon the forces existing at three interfaces; (a) the *air-water interfacial tension*, commonly spoken of as the surface tension of the water, (b) the *air-oil interfacial tension,* or surface tension of the oil, and (c) the *oil-water interfacial tension.* The behavior of the oil is fixed by the sign and value of its *spreading coefficient,* thus:

$$C = S_w - (S_{ow} + S_o)$$

Where C = the spreading coefficient (dynes/cm)
S_w = the air-water interfacial tension (dynes/cm)
S_{ow} = the oil-water interfacial tension (dynes/cm)
S_o = the air-oil interfacial tension (dynes/cm)

When the spreading coefficient is positive, that is, when the sum of the oil-water and air-oil interfacial tensions is less than the air-water interfacial tension of the uncoated water, the oil will spread. If the sum of the oil-water and air-oil interfacial tensions exceeds the air-water interfacial tension, the oil will maintain itself as an intact globule on the surface of the water. It is apparent that the positive coefficient of an oil cannot exceed the value of the air-water interfacial tension, or approximately 72 dynes/cm. for the common range of temperatures of most mosquito breeding waters.

Oils with high spreading coefficients spread rapidly and form thin films—these offer the advantages of economy of materials and rapid, positive covering. On the other hand, they contain a relatively large proportion of water soluble materials and are more likely to produce temporary or unstable coatings. Murray has recommended the specification of oils with spreading coefficients in excess of 17 dynes/cm.; Gray suggests a slightly higher minimum value, about 24 dynes/cm. The permanency of the oil film is conditioned also by its chemical composition.

The spreading behavior of oils is modified by the surface tension of the water itself. Clean natural waters have surface tension values that usually lie within 0.5 dynes/cm. of that of distilled water—inorganic salts increase these values and most soluble organic materials lower them.

Waters rich in soluble organic matter, such as bog extracts, swamp waters, and streams and ponds receiving domestic or industrial pollution may show markedly lower surface tensions. The presence of soaps and oily materials also depresses the surface tention values. In the control of nuisance mosquito larvae, many of which develop in polluted or semi polluted waters, this is a matter of considerable importance since the spreading coeffecient of the oil is lowered by the decreased surface tension of the water. Oils

which spread with moderate force on clean waters may not spread on polluted water surfaces. The growth of bacteria at the surface of clean water also reduces its surface tension; stored samples commonly show this phenomenon. Most anopheline species, however, breed in relatively clean waters which usually show surface tension values close to 72 dynes/cm. and oils used in their control are not so markedly limited by the surface tension of the water itself.

Behavior of Oils on Biologically Coated Water Surfaces:

Thin films of bacteria and other micro-organisms growing at the water surface mechanically change the elastic behavior of the normal air water interface. Clean water interfaces are infinitely elastic; equivalent lines of tension extend in all directions over the interface from every point in the surface. When fine particulate materials become imbedded in the interface, or when the surface itself is covered with inelastic bacterial slimes, cell stuff, or fine flotage, the effectve pull along these lines is diminished by an amount equal to the crushing strength of the biological coating.

Under many conditions the coating may be so thick or so strongly adsorbed on the air-water interface that the residual tensions are insufficient to "spread the oil." The previously stated formula for the spreading coefficient may be modified to include this phenomenon, thus:

$$C_b = (S_w - F) - (S_{ow} + S_o)$$

C_b = the spreading coefficient of oil on biologically coated water. (dynes/cm.)

F = the crushing strength of the biological film (dynes/cm.)

The force with which oil may spread on coated water differs from its spreading coefficient as determined on clean water in the laboratory by a value equal to the crushing strength of the biological film.

The behavior of spreading oils on clean and coated surfaces is represented graphically in Figure 1. In observing this it should be borne in mind that the spreading oil is not, strictly speaking, stretched over the freshly oiled surface by the retreating air-water interface. The actual mechanism of spreading is not clear, though the active forces seem to be restricted to the boundary between the oiled and clean water. For practical purposes, however, it is adequate to represent the behavior of spreading oils by the simpler, though fictitious, mechanical equilibrium given in Figure 1.

Measurement of the Crushing Strength of Biological Coatings:

Under field conditions it is most convenient to measure the resistance offered by surface coatings of biological origin to the spread of oils by applying the method developed by Adam for the

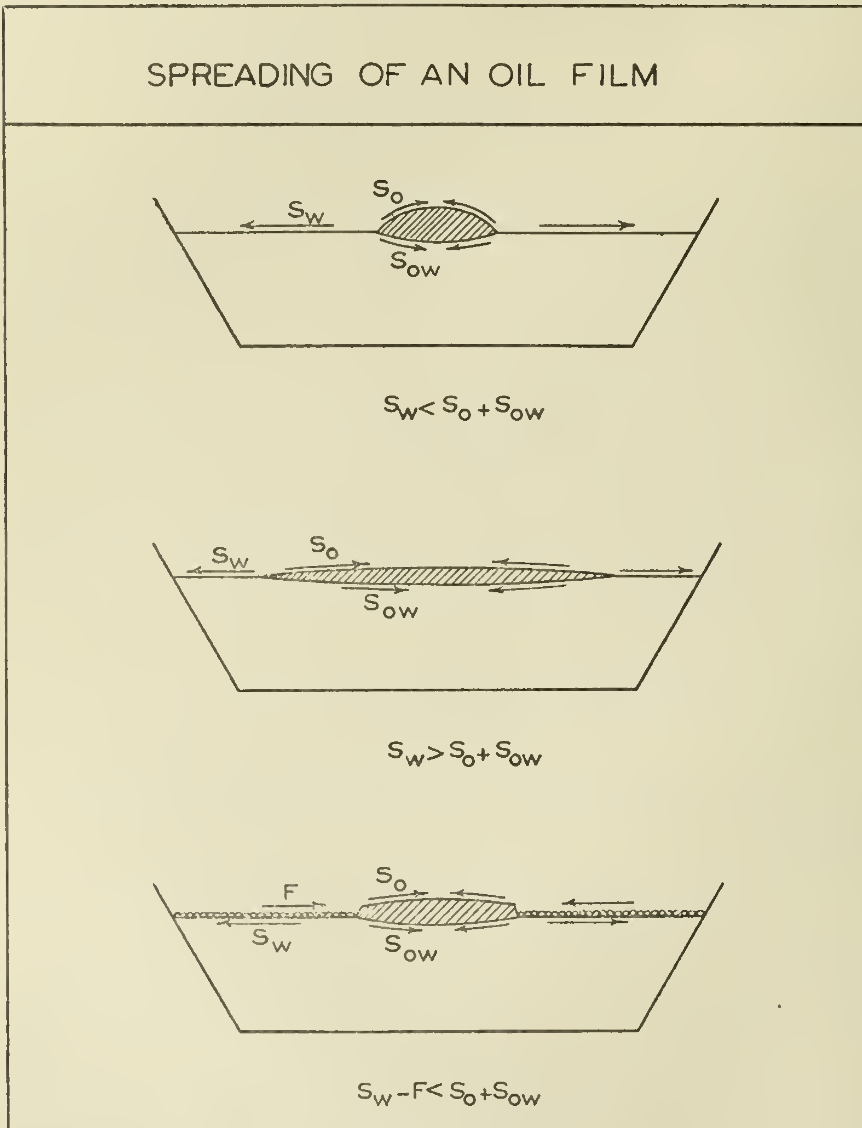


Figure 1

detection of oil contamination of sea water (1). In this procedure a series of droplets of oil-lauryl alcohol mixtures having graded spreading coefficients are applied to the water surface to be studied. The crushing strength of the coating to which they are applied is equal to the spreading coefficient value of the first member of the oil mixture series (applied in ascending order* that shows a tendency to spread.

Field Observations on Crushing Strength of Biological Films:

During the summer of 1940, measurements were made upon twenty-eight permanent ponds and anopheline mosquito breeding pools near Tallahassee, Florida. These ponds were examined frequently and under a variety of conditions of wind, rain, and summer temperature. In addition, measurements were made on over a hundred unclassified breeding sites visited during an observational tour of malaria control projects in southern Georgia, nothern Florida, Alabama, and the Tennessee Valley Authority. The phenomena to be described are general, indeed they can be reproduced in any quiet body of water from a finger bowl to a large lake.

The spreading oils used in these experiments were prepared according to Adam's method; a fifteen member series with a spread-coefficient ranging from 1.5 dynes/cm. to 43.0 dynes/cm. in approximately 3 dyne intervals.

These were dispensed into 25 ml. glass stoppered dropping bottles and securely arranged in a sturdy field rack. The oils were originally calibrated by means of a NuNuoy tensiometer, modified for interfacial tension measurement. Later, these values were checked with a Langmuir-Adam trough. The agreement in the range of spreading forces, 20 to 40 dynes/cm., was excellent; below and above these values the agreement was satisfactory.

Microscopic equipment including contact slides for sampling the water surface was also carried, and when weather permitted direct examinations and identification of surface organisms were performed in the field.

The measurements of the crushing strength of the films were made by dropping single droplets of oil from ascending members of the series until positive spread was obtained. The water at the windward and leeward margins of the ponds, in protected bays, and in the vicinity of emergent plants was examined separately.

Crushing Strength of Biological Coatings on Quiet Waters:

In protected waters such as those produced in seepage ponds,

drains with steep banks, shaded swamps, and heavily vegetated pools heavy films are most frequently formed. These are often evident as slimes supporting small bubbles of gas, as dusty coatings, or as brittle encrustments of organisms. When winds cannot reach them, the crushing strength of these films is usually low, rarely in excess of 5 dynes/cm. Oils with a spreading coefficient higher than this are able to spread. However, the film fragments swept aside by the oil film may accumulate at the margins of the pond, in streaks, rafts, and islands about flotage or emergent vegetation. The highest crushing forces measured in films of this type ranged about 20 dynes/cm. No larvae were found in these sites and it was the opinion among the investigators with whom the writer discussed the problem that anopheline larvae do not develop in waters coated by thick, standing films.

Crushing Strength of Biological Coatings at the Leeward Margins of Ponds:

The spreading of oils is most strikingly retarded when the wind compresses accumulated films against them at the leeward margins of ponds. This compression factor becomes effective at very low wind velocities, when breezes barely ripple the water surface.

Very gentle winds transport films developed over the whole water surface to the leeward margins where they buckle and fold to produce scums of considerable thickness. The wind compressed films act as "squeeges"—when they accumulate to sufficient thickness and are driven by sufficiently strong winds, they sweep the oil films from the whole surface into scattered globules, nets, and streaks.

The significant feature of this phenomenon is that winds that may be barely felt and which move floatage at less than a mile an hour may prevent spreading oils of the highest available coefficient from forming films when these are applied within coated areas at the leeward margins of ponds. That this squeege effect is a function of the biological film and is not due to compression of the oil by the wind directly may be demonstrated by dropping test oils at measured intervals from the shore. In Table 1 the spreading forces of graded oils necessary to break the film at increasing distances from the leeward shore of a shallow, grassy, sink pond exposed to gentle wind is given. The water surface itself was not ruffled and the film collected was almost invisible.

Table 1

Spreading Force Resisted by Film at Different Distances from Leeward Shore

Distance from Shore (Meters)	*Spreading Force Resisted* (dynes/cm.)
Edge	>39
1 to 4	>39
5	29
6	20
7	18
8	9
9	5
10 and on out	< 3

These values afford a single example. There seems to be no regularity in the shoreward gradient other than a general increase in the force required to produce spreading of oil. It is likely that wind velocities, time of accumulation, and composition of the biological film are determining factors. In the pond represented, it is apparent that the larvicidal oils with the spreading forces below the recommended 17 dynes/cm. would not spread within the five meter line. It will be pointed out later that the practical limit of such an oil under conditions of coating is increased enormously by application in heavy streams of water. The purpose of this demonstration is to show that the spreading force of the oil alone may not be sufficient to form an oil film over a biologically coated area. To make the oil effective the sheet structure of the coating must be destroyed.

Compression of Biological Coatings in Embayments:

If these surface supported films are regarded as "Two dimensional fluids" it will be anticipated that lines of equal crushing strength, thickness, or states of folding will extend perpendicular to the path of the wind and will not lie parallel to the shore lines. This is visibly demonstrated by the alignment of spreading oils placed on the water to the windward of the accumulated film. Essentially the same type of evidence is furnished by carefully mapping the position and behavior of droplets of oil of any single spreading coefficient.

A very common feature of ponds with irregular, embayed, swampy margins is the concentration of fine flotage in sheltered

pockets not subject to the direct action of wind. These films, however, exist under the maximum pressure exerted by the wind upon the open areas of the pond. In their protected position they tend to be much more permanent than the films subject to wave action

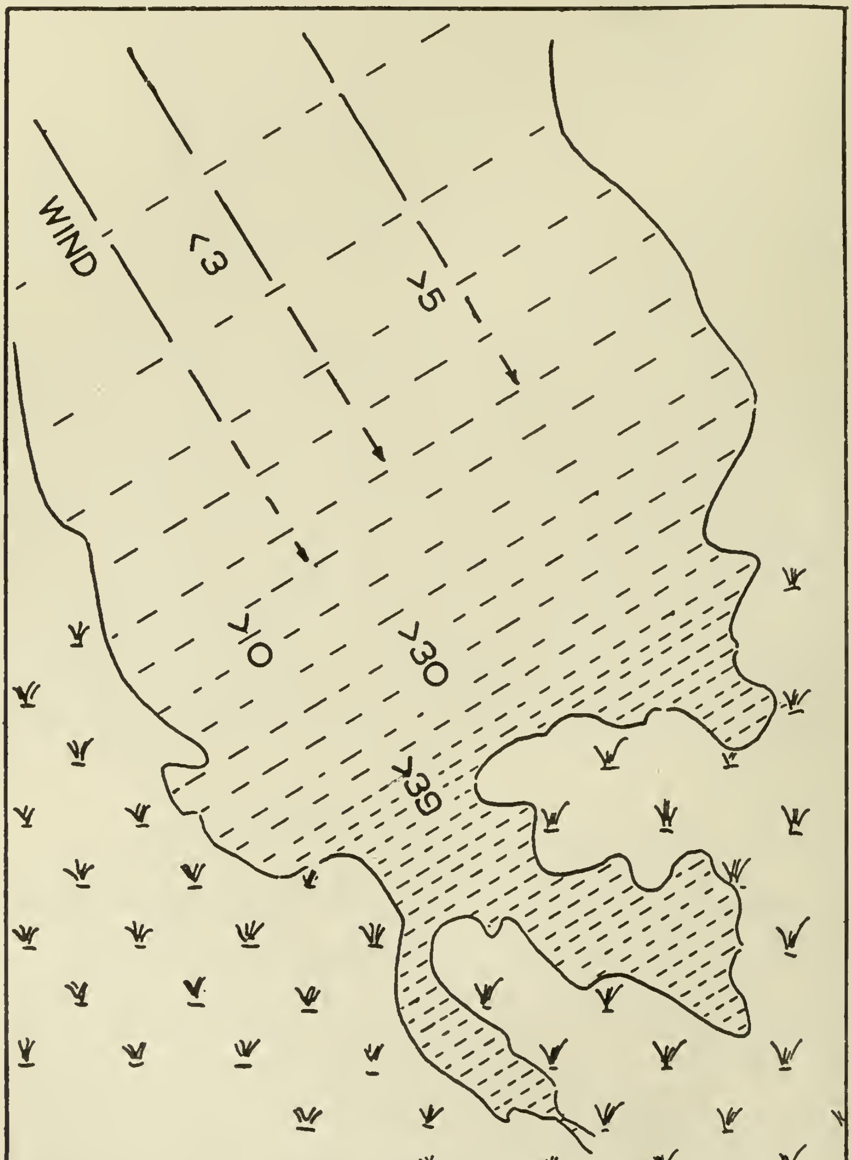


Figure 2

along the exposed shores of the same pond. Oils of the highest available spreading coefficient may not spread upon these compressed coatings, though they may be split apart by oils of intermediate spreading values when the winds drop or change direction. Quiet, heavily vegetated embayments, such as these, make up a large fraction of the breeding areas that must be controlled by oils applied by hand gear; they are, in general, inaccessible to boats and power spray equipment.

Miscroscopic Examination and Composition of Biological Coatings:

At the beginning of the investigation efforts were made to determine the relative amounts of organic material and organisms entrapped in the water surface and in the plankton of the same waters. The concentration of surface materials by the wind made this operation impossible, and full attention was given to determining the structure of the films itself.

As would be expected, the organisms forming the films varied widely from pond to pond, from time to time, and within the same stations. Species of *Arcella,* free amoebae, *Euglena, Mallomonas, Phacus,* and other surface swarming forms were common. *Zygnema, Mougeotia, Spirogyra, Arthrodesmus, Closterium, Micrasterias,* and *Oocystis* occurred most frequently among the algae. In addition, trapped insects, larval moults, worms, pollen grains, plant debris, road dust, and soot mixed with the films.

However, the essential film forming complex consisted of bacterial cells and gelatinous matrix material of bacterial origin. This seemed to form the basic membrane upon which air borne organisms and debris fell and to which the true aquatic forms attached themselves. It is not surprising that large proportions of bottom forms such as the desmids and armored amoebae should be found at the surface, attached to and feeding upon the bacterial slime sheet. Bacteria and their matrix materials were found on all quiet waters; in the wind concentrated coverings they formed a major part of the organic matter.

No attempts were made to identify the bacteria though a number of forms were isolated for description. The bacterial flora seems to vary from locality to locality and within the same field. Sheathed filamentous forms were common; they were especially prominent in "rusty" waters where they produced characteristic floating, brownish flocs a millimeter or more in diameter.

It is important to recognize the role that the matrix in which

the bacteria are imbedded plays in determining the elastic properties of the biological film. The force required to press the film into folds is set by the bond between the lower surface of this matrix sheet and the water that it covers—films of dust and soot in which there is little matrix structure are readily dispersed by shifting winds and gentle wave action.

Mechanical Destruction of Biological Films:

Most biological films on natural waters are periodically destroyed by rains, splashing, whipping, wave action, and other forms of surface agitation that tear, fold, or wet their surfaces. Rains are of primary importance. Relatively gentle precipitation, even heavy mists, are capable of destroying the matrix sheet. Winds rapidly strand or disperse the torn fragments; wetted flocs of the folded matrix settle rapidly to the bottom.

On Pickwick Reservoir on the T. V. A. a number of observations were made on the destructive effect of water borne oil delivered from motor pumps. In test the oils alone had negligible spreading coefficients, less than 5 dynes/cm. When applied as a heavy spray, however, they formed films readily over areas that bore resistant biological coatings under wind compression. Only a light whipping of the surface by spray droplets was necessary to fragment and wet down the biological film; the suspended oil spread as though on a clean surface.

The advantages and economies of applying oil on streams of water have been recognized for some time by practical operators. The observations of this paper emphasize the effectiveness of this method of oiling over procedures that must depend upon the high spreading coefficient of the oil alone. To extend the advantages that come with whipping the water surface, it is most desirable portable apparatus be developed for treating the protected areas that are normally oiled by hand.

Oil sprays mechanically destroy films over areas upon which the droplets fall, but the radius of projection is low and it is uneconomical to employ a stream or heavy spray of oil for the agitation of floatage, drift, and emergent vegetation. The scattering of oil coated sands or sawdust and application by brushing or dripping are subject to the same limitations. To insure the effective spread of larvicidal oils of any composition and spreading coefficient, areas coated with biological films, especially those at the leeward margins of ponds, must be subject to whipping or splashing agitation.

Summary:

1. When natural waters stand undisturbed by wind or wave action, thin membranes of bacteria, protozoa, algae, dusts and larger floating materials form upon their surfaces.

2. These films vary in thickness and composition. Light winds concentrate them at the leeward margins of the ponds, pools, or lakes on which they develop.

3. These films resist the spread of film forming larvicidal oils. Their crushing strengths commonly exceed the spreading forces exerted by oils and oil mixtures used in practical mosquito control.

4. The resistance of biological films to crushing by spreading oils may be determined quantitatively by observing their ability to block the spread of members of a series of oils of known spreading force values.

5. To insure the effective spread of larvicidal oils on coated waters it is necessary to biological film by agitating the water surface.

Bibliography

1. Adam, N. K., 1937, A Rapid Method for Determining the Lowering of Tension of Exposed Water Surfaces, with some Observations on the Surface Tension of the Sea and Inland Waters. *Proceedings of the Royal Society of London*, Section B, 122: 134-140.

2. Burdon, R. S., 1940, Surface Tension and the Spreading of Liquids, pp. 1-17, 27-35, 47-66. Cambridge University Press.

3. Herms, W. B., and H. F. Gray, 1940, Mosquito Control, pp. 175-179, *The Commonwealth Fund*, New York City.

4. Murray, D. R. B., 1939, The Spreading Power of Oils and Methods of Increasing It, *Bulletin Entomological Research*, 30, (2): 211-236.

MALARIA-CONTROL, DITCH-LINING EXPERIENCE IN A SOUTH GEORGIA COUNTY*

JUSTIN ANDREWS, R. S. HOWARD, JR., AND
E. ARCHER TURNER

In the past few years considerable progress has been made in the use of concrete ditch-lining in malaria-control drainage. Design, construction, and installation of concrete lining have been discussed at great length but there is still a lack of accurate information on the economics of this malaria-control practice. This lack is especially significant to the public-health malariologist interested in obtaining cost data to apply to a job at hand or to plan a malaria-control program for a county or community.

This paper is concerned with a study of the costs of precast ditch-lining in urban malaria control, observations on the efficiency of this practice as a malaria-control measure and comparison of the functional desirability and costs of various types of precast inverts.

Participating agencies in this study were the Rockefeller Foundation, through the Georgia Department of Public Health, City of Quitman, Brooks County Health Department and the Work Projects Administration of Georgia.

Locale, Materials and Methods

1. *Locale*: In Georgia, generally, malaria may be considered a rural disease but there are some towns, usually small ones, that may be classified as malarious. In such places the malaria endemicity is frequently associated with open, unlined, drainage systems which offer, by reason of their lack of maintenance and faulty design, favorable environments for *Anopheles quadrimaculatus* production.

The City of Quitman (population 4449), seat of Brooks County (population 20,497), in south Georgia, is such a town

---

**Contribution No. 13* from the Division of Malaria and Hookworm Service, Georgia Department of Public Health, Atlanta, Ga. Grateful acknowledgment is made to the Rockefeller Foundation, City of Quitman, Brooks County and the Work Projects Administration of Georgia who cooperated with funds and other material resources to make this study possible.

TABLE I

Reported Death Rates from Malaria per 100,000 Population

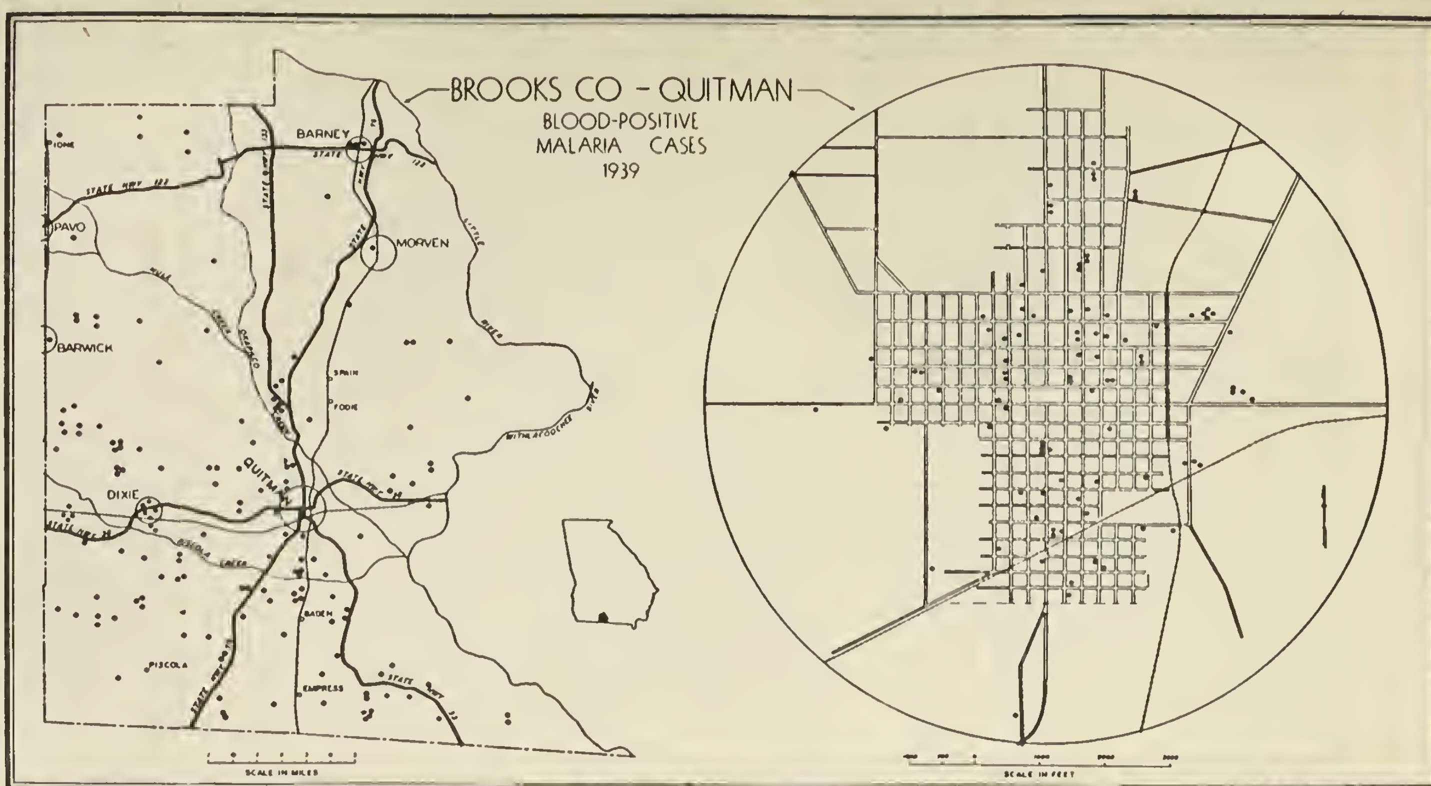
Year	*Georgia*	*Brooks County*	*Quitman*
1932	10.7	23.0	47.4
1933	12.2	68.4	117.6
1934	13.9	58.8	46.7
1935	12.8	31.4	46.3
1936	19.8	57.9	91.9
1937	7.6	22.1	68.4
1938	4.7	8.8	–
1939	3.2	4.3	–
1940	2.8	4.9	–

with a malaria history comparable to that of certain rural, malarious areas of the State (see Map 1 and Table 1). It is low-lying (average elevation, 160 feet above sea-level), is sandy and has a mean ground-water level about three feet below ground elevation. Biological surveys in and around Quitman in 1938 and 1939 indicated that the only significant *A. quadrimaculatus*-breeding was taking place in the many open ditches of the town, which were clogged with vegetation, contained numerous potholes and had silted so badly that water was impounded for considerable lengths in many of them.

Malaria in Brooks County is not uniformly distributed, as is shown in Map 1, due not only to variations in the accuracy and completeness of case-reporting but to the topography and geology of the county. The northern two-thirds is rolling and variable in contour, most of the malaria being associated with man-made impoundments. The lower third is flat and underlain with Ocala limestone (see Fig. 4 in Boyd and Ponton, 1933). Its surface is dimpled with numerous, water-holding, lime-sink depressions many of which are known to be breeding-places of *A. quadrimaculatus.* Reported malaria death rates per 100,000 population for Brooks County are shown in Table 1 in comparison with those of the State and the City of Quitman.

2. *Plant and Equipment:* The casting plant, furnished by the City, consisted of a storage house for cement and tools, a field office and a concrete floor (12 ft. x 60 ft. with shed) to be used for a casting platform.

An overhead sprinkling system for curing was installed along one side of the plant yard.


BROOKS CO - QUITMAN
BLOOD-POSITIVE
MALARIA CASES
1939
BARNEY
MORVEN
PAVO
BARWICK
DIXIE
QUITMAN
SPAIN
PIDCOCK
BADEN
PISCOLA
EMPRESS
SCALE IN MILES
SCALE IN FEET

Map 1

The cost of the plant and equipment is shown below:

Item	*Cost*
1 Cement Mixer, 3½ s (Ransome, gasoline motor)	$200.00
1 24-inch pipe mold, with header and 10 pallets	123.44
1 Eclipse hand-tile machine with molds for 4 and 6-in. tile	140.00
Sprinkler system, 220 ft., ¾ inch pipe	17.60
Nozzles, and cut-off valves for sprinkler	4.50
Casting floor (4-inch concrete slab) 12 ft. x 60 ft. with roof	55.00
House, for storage, etc.	25.00
Modified Panama-invert forms (materials and labor) to make 54 feet of inverts (9 sets of 2 3-foot sections each)	68.48
Pipe invert forms (materials and labor) to make 124 feet of 24-in and 24 feet of 18-inch	65.50
Incidentals (tamping rods, wires, etc)	10.00
Total	$709.52

Miscellaneous hand tools were supplied by W. P. A. One 1½-ton truck for hauling materials, transporting inverts, etc., was furnished by the City of Quitman.

3. *Materials:* Materials used on this project included 790 bbls. of cement at $2.60 per barrel, 206 cu. yd. of sand at $1.90 per cu. yd., 513 cu. yds. of gravel at $2.10 per cu. yd. and 10,413 sq. yd. of grass sod at $0.15 per sq. yd. (labor and transportation only), with which approximately 4.15 miles of ditch were paved.

4. *Operation of Project:* Previous to organization of this project, the County Health Engineer had experimented with an invert form that could be constructed with unskilled labor and little material cost. The inner form consists of sections of pipe, partly buried, against which the inverts are poured. The buried pipe has a concrete curb along each side into which is fixed a piece of wooden two-by-four (Plate I, Fig. 1 and 2). Two sheets of 22-gauge G. I. metal, with one-inch angle-irons attached to the edges are fastened to the two-by-fours and serve as the outside form. The angle-iron edges, wired together, form the square footing of the invert bottom. The inverts are poured with butt joints, using wood or metal dividers, in 4-foot sections with a wall thickness of 1¾ inches; no reinforcement was used. The invert cast against the outside of 24-inch pipe has a chord of 27½ inches, a depth of 8½ inches; the 18-inch pipe invert has a chord of 19½ inches, a depth of 5½ inches.

The modified Panama inverts used were cast in forms designed by Mr. C. H. Fields, Chatham County Malaria Control Engineer.

These were made of wood and metal (Plate I, Fig. 3 and 4) and differ from the original Panama form chiefly in their cross-section which is bounded by a parabolic segment rather than the arc of a circle. The slab is two inches thick with a 20-inch chord and depth of six inches.

Various concrete mixes were experimented with at the beginning of construction. A mixture of one part cement, two and one-half parts sand and three parts gravel was found to work best with all types of inverts. The amount of water used varied considerably but the concrete was a "wet" mix. A drier mix could have been employed advantageously if a vibrator had been available. Even with the wet mix, a great deal of hand tamping was necessary to avoid "honeycombing" and to give the sides and edges of the slabs a smooth, even finish. Forms were oiled with waste crank-case oil.

Inverts were poured, allowed to set twenty-four hours before the forms were removed and then were stacked on end and subjected to a fine mist-like spray. This curing was continued for at least seven days and proved satisfactory. The inverts were usually installed in "wet" ditches where curing could continue.

Precast sandtraps, 36" x 36" x 18" deep, were used at all junctions, turns, road-crossings and similar cross-drains.

Four- and six-inch sub-soil concrete tiled pipe was used in a number of places in the system. This was manufactured with private labor, hired by the City, and was charged to the project as a sponsor's contribution at local market prices. It was used in the sub-soil drainage of low areas, semi-permanent ponds adjacent to main channels, to intercept groundwater seepage and prevent bank erosion and as a substitute for paved inverts in minor laterals where the water-table was high. Saw-dust was used as the absorptive material in the sub-soil drains and has proven very satisfactory thus far. Larger concrete pipe, 24", 30", and 36", was used in cross-drainage structures. In one section, where a closed drain was necessary, several hundred feet of 24" pipe were used to accommodate a large flow of water

The labor crew, including a supervisor, two foremen, a clerk and a timekeeper, averaged about 25 men during the 14 months the project was carried on. Plant and field installation gangs were organized, the latter being divided into two units. One of these was detailed to do the coarse grading before installation and to sod the banks after the inverts were placed. The other crew brought

the ditch to final grade, installed the inverts and completed all fine finishing work.

Preceding installation, profiles were run on the ditches and the proper grade for each was determined. Battens were set at 50-ft. intervals and connected with string for checking grade. On curves, these grade checks were set every twenty-five feet or less. Alignment was maintained by lining up one edge of invert slabs with a string stretched between battens.

With the very unstable soil encountered on this job, it was important to complete the bank stabilization as soon as possible after the inverts were in place. In some instances this was not done with the result that rains, immediately following, caused considerable bank-scouring and the inverts had to be reset to grade and alignment. The blanket method of sodding was used to sod a strip two feet wide above the invert. An indigenous species of grass, known locally as carpet grass, was obtained without cost, except for labor and transportation, from nearby fields or meadows. Second-hand hog- or fence-wire was used to pin the sod blanket in place with wooden pegs. Depending on the weather, the sod was kept pinned for two weeks or more. Unless a rain was expected soon, the grass was watered thoroughly as soon as placed.

Results and Discussion

This project is not represented as being a model or demonstration example of ditch-lining; few health departments in low-income, malarious counties can afford to provide the constant, skilled supervision this would require, especially with unselected relief labor. Nevertheless, it has proven to be effective from the standpoint of rapid storm-water removal and reduction in ground-water level; it gives every promise of being equally effective as a malaria-control measure.

1. Cost of precast ditch-lining: At an overall cost of $26,657.85, 21,814 feet of precast concrete inverts with accessory structures were built and installed in Quitman; this amounts to $1.22 per linear foot of ditch-lining, a figure that will naturally depart somewhat from those of larger or smaller projects carried on in other places and at different times. Approximately 85 per cent of the footage in the City's drainage system was paved when the project was discontinued (see Plate I, Fig. 6). The cost sub-divides into gross components as follows:

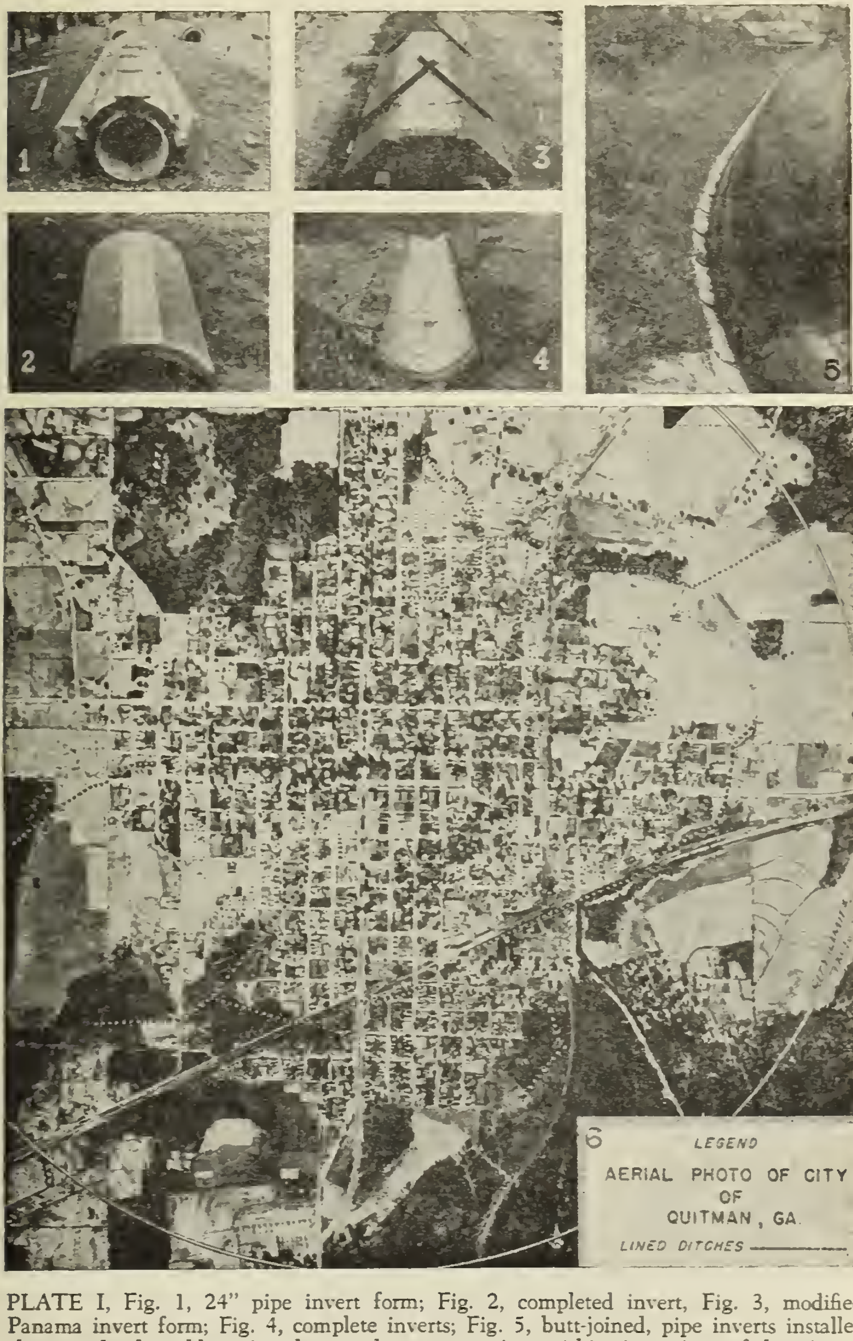


PLATE I, Fig. 1, 24" pipe invert form; Fig. 2, completed invert, Fig. 3, modified Panama invert form; Fig. 4, complete inverts; Fig. 5, butt-joined, pipe inverts installed showing bank sodding in place and grass growing within interstices of butt-joints; Fig. 6, aerial photo of Quitman, Ga., showing location of concrete ditch-lining.

	Federal	Sponsor	Total
Labor	$18,264.11	$1,278.50	$19,542.61
Non-labor (materials, transportation, equipment, etc.)	2,564.94	4,550.30	7,115.24
TOTAL	$20,829.05	$5,828.80	$26,657.85

Approximately 73 per cent of the total, therefore, was expended for labor and supervision in the Quitman project. If this is representative of general experience, it appears that labor is the most important consideration in the economics of ditch-lining practice and the one in which most compression is possible. Whether or not non-relief labor is cheaper than relief labor per unit of finished work is a debatable point but as long as federally-paid labor is available without large local contributions, it most certainly will be used. Where this cannot be had, convict labor in the states permitting its use is undoubtedly the cheapest source of man-hours.

2. *The malaria-control efficiency of concrete ditch-lining:* Considering the fact that the project was barely under way at the beginning of the 1940 malaria season and only about 60 or 65 per cent completed before the 1941 season, it is unlikely that the ultimate malaria- control effect has been felt or can be measured at present. As shown in Table I, there have been no malaria-deaths reported from Quitman since 1937 due, probably, to the activities of a full-time health unit, including a laboratory, installed during that summer. Practicing physicians in the City and, to a certain extent, in the County as well, send thick blood-films to this laboratory for diagnosis of suspected malaria cases; malaria morbidity is, therefore, better reported than in many other places. The following tabulation shows the blood-positive cases reported by the local health laboratory:

Year	Brooks County	Quitman	Percent of cases in Quitman
1938	284	105	37%
1939	334	142	43%
1940	220	88	40%
1941 (Through Oct. 31)	56	12	21%

This indicates that while the ratio of city to county cases remained more or less constant during 1938, '39 and '40, there were relatively fewer cases in Quitman than in the County in the first ten months of 1941. It remains for time to confirm or refute this trend.

3. *Comparison of the functional desirability and costs of various types of precast inverts:* Comparison is limited to the modified Panama and the locally-designed pipe inverts which differ, as has been pointed out, in the shape of their respective cross-sections, the type of joints and wall thickness. Comparative construction cost data are shown in Table II. These are average production costs based on several test runs made during periods of normal operation.

No discernible advantage to either shape of cross-section could be observed. In theory, the parabolic pattern should increase the velocity of small flows; at the diameters used, however, the difference was negligible. For all practical purposes, the flow characteristics of each invert appeared to be the same.

The lap-joint, while a trifle more difficult to cast, was definitely superior to butt-joint construction. Unless butt-joined inverts are laid on grade-boards the liklihood of individual units settling is greater than if they are lap-joined so that one section helps support the next. Of even greater importance from a malaria-control standpoint, is the fact that grassy vegetation grows readily in the interstices of butt-joints (Plate 1, Fig 5) whereas it rarely, if ever, grows through the lap-joint. This vegetation retards flow, obstructs flotage and causes siltation thus deteriorating the flow efficiency and increasing maintenance costs of the butt-joint invert.

As shown in Table II, the construction cost per linear foot of the pipe invert is one-seventh less than that of modified Panama inverts of corresponding cross-sectional area, being 14.6 and 17 cents (plus 0.4 and 1.2 cents for forms), respectively, for the 18" products. This is due to the thicker wall of the latter type. This appears to us to be the most important difference between the two. The pipe invert, equipped with lap-joint articulation, should give the same service as the Panama invert and costs less to manufacture.

4. *Use of butt-joint tile in connection with lined ditches*: Experience gained from this drainage project indicates the advisability of extending the use of sub-soil tile drainage in systems similar to the one discussed, not only in minor laterals or to intercept seepage flows for ditch-bank protection, but to substitute for concrete invert-lining in ditches. By laying butt-joint tile in percolation beds beneath ditch-bottoms, residual waters may be removed from ditches quickly, safely and cheaply. This is especially important in urban areas where concrete-lined ditches have their efficiency temporarily but frequently impaired by trash, rubbish, and other obstructive materials thrown into open ditches. Probably the main impediment

TABLE II

Cost Analysis of Precast Concrete Inverts and Accessory Structures—Quitman, Georgia

TYPE UNIT	Amount Produced	MATERIALS			LABOR		TOTAL COST IN CENTS			
		Cement (sacks)	Sand (cu. yds.)	Gravel (cu. yds.)	Unskilled	Semi-skilled	Materi-als	Labor	Per Unit	Per Linear Foot
Panama Invert (Parabolic) 20" chord 36" slab—2" thick	5,549′	0.027 @ 63.25 ¢ 17.0 ¢	0.025 @ 1.90 ¢ 4.7 ¢	0.030 @ 2.10 ¢ 6.3 ¢	0.72 m.h.@ 27.0 ¢ 19.4 ¢	0.11 m.h.@ 33.0 ¢ 3.6 ¢	28.0¢	23.0¢	51.0¢	17.0¢
24" Pipe Invert 27½" chord 48" slab—1¾" thick	13,731′	0.50 @ 63.25 ¢ 31.6 ¢	0.046 @ 1.90 ¢ 8.7 ¢	0.055 @ 2.10 ¢ 11.5 ¢	1.1 m.h.@ 27.0 ¢ 29.7 ¢	0.17 m.h.@ 33.0 ¢ 5.6 ¢	51.8¢	34.3¢	86.1¢	21.5¢
18" Pipe Invert 19½" chord 48" slab—1¾" thick	2,534′	0.25 @ 63.25 ¢ 15.8 ¢	0.023 @ 1.90 ¢ 4.3 ¢	0.028 @ 2.10 ¢ 5.9 ¢	1.0 m.h.@ 27.0 ¢ 27.0 ¢	0.17 m.h.@ 33.0 ¢ 5.6 ¢	26.0¢	32.6¢	58.6¢	14.6¢
Subsoil Tile* 4" concrete	254′	0.02 @ 67.0 ¢ 1.34 ¢	0.0022@ 1.90 ¢ 0.42 ¢	— — —	0.074 m.h.@ 27.0 ¢ 215 tile in 16.0 m.h.	— — —	1.8¢	2.0¢	3.8¢	3.8¢
Subsoil Tile* 6" concrete	988′	0.033 @ 67.0 ¢ 2.2 ¢	0.0037@ 1.90 ¢ 0.7 ¢	— — —	0.1 m.h.@ 27.0 ¢ 160 tile in 16.0 m.h.	— — —	2.9¢	2.7¢	5.6¢	5.6¢
Precast Sandtrap 36" x 36"—18" depth 2" wall	31	—	—	—	—	—	$4.41 (Estimated)			

Panama and pipe invert forms cost 1.2 and 0.4 cents per foot of invert produced—and were in good condition when project closed.

*Private Labor Paid by City

CONCRETE FORMULAE USES	Cement	Sand	Gravel
All Inverts	1	2½	3
Sandtraps	1	2½	3
Subsoil Pipe	1	3	0

to its use is the fact that the tile pipe-line cannot be seen whereas the concrete inverts, carrying a crystal-clear flow of water within nicely sodded banks, provide a constant and sightly testimonial to engineering skill and industry.

Conclusions

In a ditch-lining project made possible by the cooperative efforts of the Rockefeller Foundation, the Work Projects Administration, city government, and state and local health agencies working together in a small city in South Georgia, 21,814 feet of various types of concrete inverts with accessory structures were built and installed at an overall cost of $1.22 per linear foot.

Of this cost, 73 percent went for labor.

The current trend of malaria incidence in the city in comparison with that in the surrounding county suggests that malaria morbidity is diminishing faster in the city than the county since the installation of ditch-lining.

No advantage in flow efficiency was observed in ditches lined with parabolic-shaped invert sections in contrast to those with arc-shaped sections.

Lap-joined inverts were shown to be superior to butt-joined inverts from the standpoint of malaria-control considerations.

Inverts cast against pipe cost less than the modified Panama type of invert. Otherwise, except for articulation design, they appeared to be equally serviceable.

REFERENCE CITED

Boyd, M. F. and G. Ponton. 1933. The recent distribution of malaria in the Southeastern United States. Am. J. Trop. Med. 13: 143.

Map 1 Outline map of Brooks County and the City of Quitman, Ga., showing known locations of blood-positive, malaria cases in 1939.

CIRCULAR JOINT AND CONCRETE FORM DESIGN FOR PRECAST INVERTS FOR MALARIA-CONTROL DITCH-LINING*

W. A. Legwen and Louva G. Lenert

Only in recent years has installation of invert paving in existing malaria-control ditches reached its greatest development. Paving of the normal channel surface was first practiced and advocated by Mr. Le Prince in Panama around 1905.[1] Later work in Panama saw the development of precast concrete inverts and most present day precast inverts are similar to or are modifications of the original Panama invert. Other types in general use at present consist mainly of sections of a circle. One type, neither circular nor parabolic, has been advanced by the Portland Cement Association.[2] This invert is made up of three or more flat slabs with sloping plane edges. Each slab is bound to parallel slabs by two No. 8 gage wires which pass thru it at its quarter points. These slabs are easily and cheaply formed using a wooden gang mold. However, the lack of end joints, the necessity of wiring, and the limitations of invert design offered probably account for its failure to be widely adopted by malaria-control workers.

In general, the Panama or modified-Panama invert is cast in an inverted position. The curved form is permanently placed, the side and end forms hinged or slotted for removal, and the actual base formed by a straight edge after the form is filled. For a form of this type to be durable, either thick sheet metal or heavy lumber must be utilized. The metal forms are prohibitive in cost for all but the largest installations and the less durable but more economical wooden forms are still too costly for small scale installations and require skilled labor maintenance. The circular sections are usually cast with metal pipe forms into which two, three or four spacers or dividers are placed to separate the inverts. After being filled, the forms are removed and the castings allowed to remain on the base pallet until sufficiently hardened to remove to the curing area. The cost of these forms, while cheaper than the metal parabolic forms, is too large to be amortized on small installations.

---

*From the Division of Public Health Engineering, Georgia Department of Public Health, Atlanta, Georgia.

In addition to the cost limitations of the circular and parabolic forms there is a limitation of invert section design. The design of the invert section is limited to the number of form widths or radii at hand unless side slabs are used. When side slabs have been used, the connections with the invert have been made with angular joints, with which full bearing on the connection is possible only at the angle for which the joint was designed.

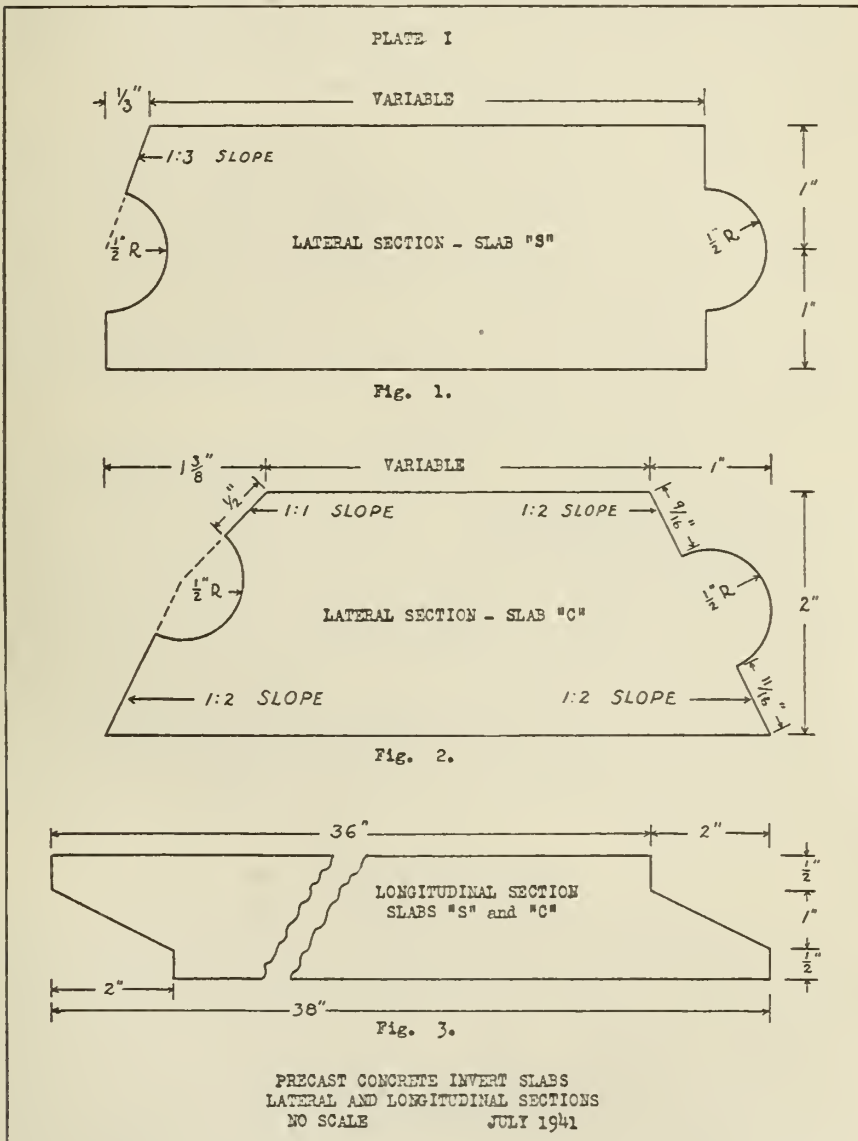
In order to secure the maximum amount of precast invert installation possible with any sum of money the form costs must be reduced to a minimum. It is also desirable that the forms be durable but of simple construction, made of materials normally on hand or easily obtained, and yet be of such nature that a maximum number of invert sections may be cast from a minimum number of forms. With these requirements in mind a new type and method of pre-casting invert slabs have been designed.

In Plate I are shown the lateral and longitudinal sections of the invert slabs with the usual type joints employed. Both of the slabs shown have a thickness of 2", identical end joints, 1/2" radius circular side joints, but the slopes of the side joints differ. On the side slab "S," shown in Fig. 1, the male joint "R" is fully semi-circular, equally spaced from top and bottom of slab, and protrudes from a vertical plane. The female joint "L" on this slab is not fully semi-circular, is equally spaced in regard to the top and bottom slab surfaces, the lower plane surface is vertical and the upper plane surface on a 1 : 3 slope. The top width of this slab is 1/3" less than the bottom width. In the center slab "C," shown in Fig. 2, the male joint "R" is on a 1 : 2 slope and the junction of the upper plane surface and the semi-circle is at a point 9/16" from the slab surface as measured along the slope. The female joint "L" of this slab is not fully semi-circular, the lower plane surface is on a 1 : 2 slope, the upper plane surface on a 1 : 1 slope and the junction of the circular portion and the upper plane surface is at a point 1/2" from the slab surface as measured along the slope. The top width of this slab is 2 3/8" less than the bottom width. The longitudinal sections of both slabs are identical as shown in Fig. 3. They have an overall length of 38", end joints 2" wide, sloping 1" beginning at a point 1/2" below the upper surface and ending 1/2" above the lower surface.

In Plate II, Figs. 4, 5, 6, and 7 are shown the basic slabs "C" and "S" and the modified slabs "CS" and "SC". Slab "CS" has the

sloping left joint and the vertical right joint and slab "SC" has a vertical left joint and sloping right joint.

In Plate III, Fig. 8 are shown joint combinations made with the right joint of the "S" slab and the left joint of the "C" slab and also the joint combinations made with right joint of "C" slab



and left joint of the "S" slab. Both combinations permit a range of change of angle of 26 degrees 35 minutes to 45 degrees or in terms of slope from 2 : 1 to 1 : 1. It will be noted that at all times in the described range there is full contact or bearing on the circular joint and at the extremes there is also full bearing on one of the plane sections. This is true also of all of the joint combinations subsequently described. In Fig. 9 are shown possible joint combinations using three "C" slabs. Range of change of angles from 53 degrees 10 minutes to 71 degrees 35 minutes or in terms of slope from 1 : 1 1/3 to 1 : 3.

In Plate IV, Fig. 10, are shown joint combinations using three "S" slabs. Range of change of angles from 0 degrees to 18 degrees 25 minutes or in terms of slope from 0 to 3 : 1. In Fig. 11 are shown joint combinations using one "S" slab and two "C" slabs. Range of change of angles from 26 degrees 35 minutes to 45 degrees or in terms of slope from 2 : 1 to 1 : 1. In Fig. 12 are shown joint combinations using three "S" slabs, two of which are inverted. Range of change of angles from 0 degrees to -18 degrees 25 minutes or in terms of slope from 0 to -3 : 1.

In Plate V, Figs. 13, 14, and 15 are shown invert sections composed of only two slabs. This V type of invert may be used for small capacity sections alone or can be used for the center section of larger inverts. In Figs. 16, 17, and 18 are shown inverts consisting of three slabs. By varying the width of the individual slabs and joint angles a close approximation of most of the smaller inverts in use at present may be made. In Figs. 19, 20, and 21 are shown inverts consisting of more than three slabs. An almost infinite number of such combinations may be made by varying the width of the individual slabs and the angles of the joints. In Fig. 20 is shown an invert that will closely approach the circular or parabolic types.

Casting Procedure

For the initial plant installation it is necessary to have one or more molds of each of the two basic slabs made of wood, metal or other material. These molds should be accurately made in all details as shown in Figs. 1, 2, and 3, Plate I, and the top width may be reduced to a minimum of about 2". In addition, two end forms for each mold are necessary. These end forms should have the same slope and thickness dimensions as the mold end joints, an overall width of about 4" and a length of 24", though this may be varied.

These molds and end forms can be made of wood at almost any wood working or millwork shop at a moderate cost. The lumber is first sized to 2″ thickness and desired width and cut to an overall length of 38″ for the molds and 24″ for the end forms. The mold edges are then cut to the desired slopes with a tilting circular saw

PLATE II

Fig. 4. Basic center slab "C"

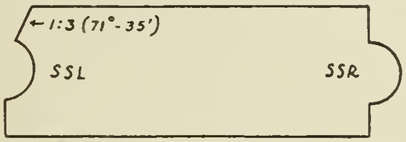


Fig. 5. Basic Side Slab "S"

LEGEND:

CSL = "C" Slab - Left joint
CSR = "C" Slab - Right joint
SSL = "S" Slab - Left joint
SSR = "S" Slab - Right joint

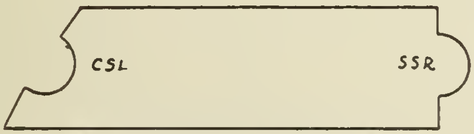


Fig. 6. Modified slab " C S "

Fig. 7. Modified slab " S C "

PRECAST CONCRETE INVERT SLABS
TYPICAL LATERAL SECTIONS
NO SCALE JULY 1941

and the female joints made by removing the designated section with a 1/2" radius semi-circular shaper. The male joint can be made by nailing on a 1/2" radius round strip at the desired point. Another method of making the male joint is to remove a semicircular section with the 1/2" shaper and then insert a dowel of

PLATE III

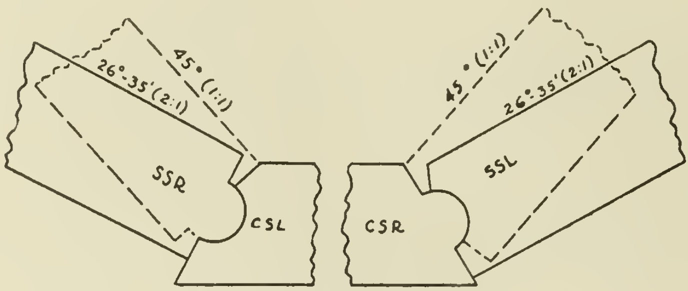


Fig. 8. Center slab with 2 side slabs

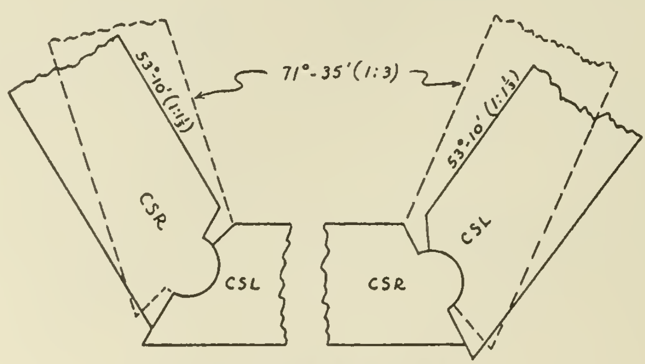


Fig. 9. Three center slabs

PRECAST CONCRETE INVERT SLABS
JOINT COMBINATIONS
NO SCALE JULY 1941

corresponding radius. This method guarantees the accurateness of the two joints. The end forms and the end joints of the molds are then cut to the desired dimensions with two cuts of the tilting saw.

In Plate VI, Figs. 22, 23, and 24, are shown the plan, section, and side elevation of the side-form casting layout. In addition to the

PLATE IV

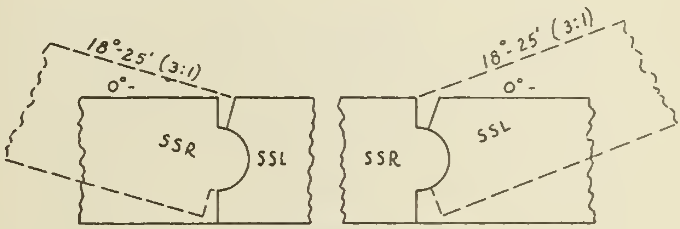


Fig. 10. Three side slabs

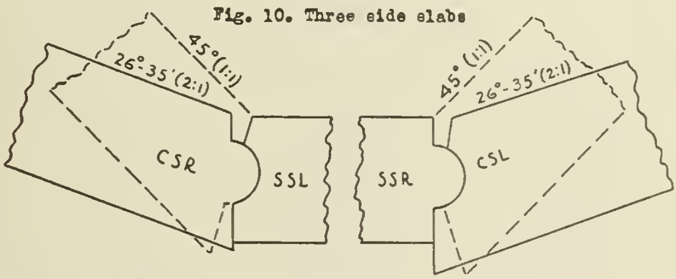


Fig. 11. Side slab with two center slabs

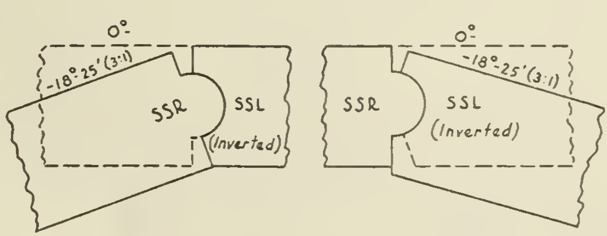
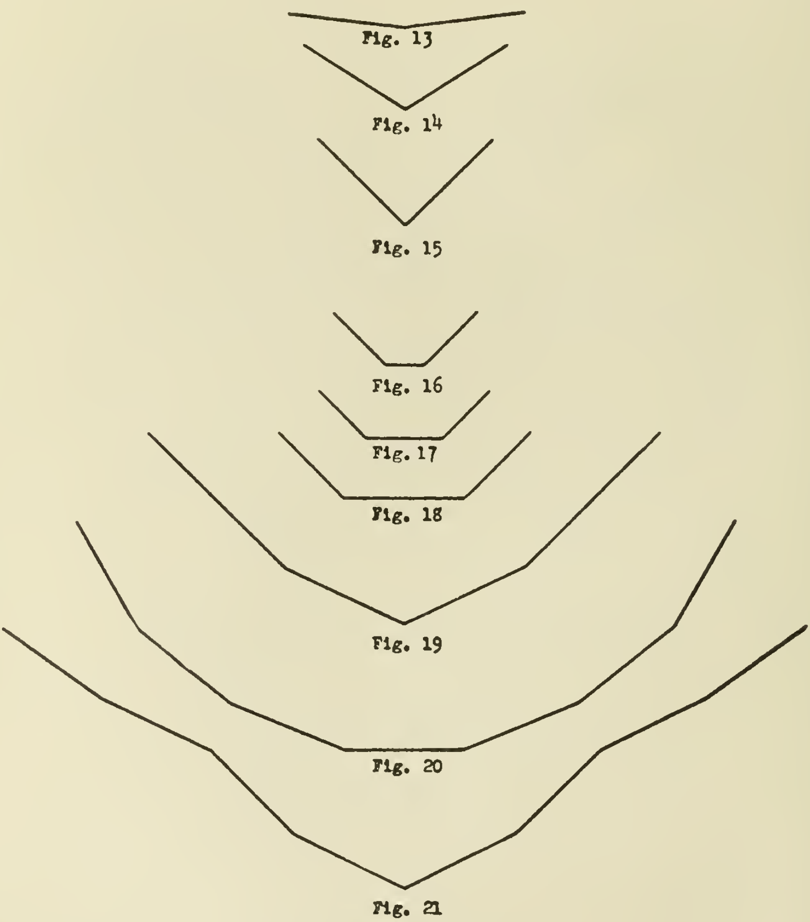


Fig. 12. Three side slabs - two inverted

PRECAST CONCRETE INVERT SLABS
JOINT COMBINATIONS
NO SCALE JULY 1941

molds and end forms, two side forms, two binding bars, and two wedges are necessary for each mold. These are easily made and do not require first grade lumber. The side forms should have the same length and thickness dimensions as the mold and a width of approximately 1" to 2." The wedging bars have a block nailed

PLATE V



PRECAST CONCRETE INVERT SLABS
TYPICAL INVERT SECTIONS
NO SCALE JULY 1941

on one end at right angles and a wedge nailed on the other end on the same side. The distance between the adjacent edges of the block and wedge should be approximately 43". Two other wedges with sloping sides coresponding to the nailed wedges should be provided. The mold end forms and side forms are now placed in

PLATE VI

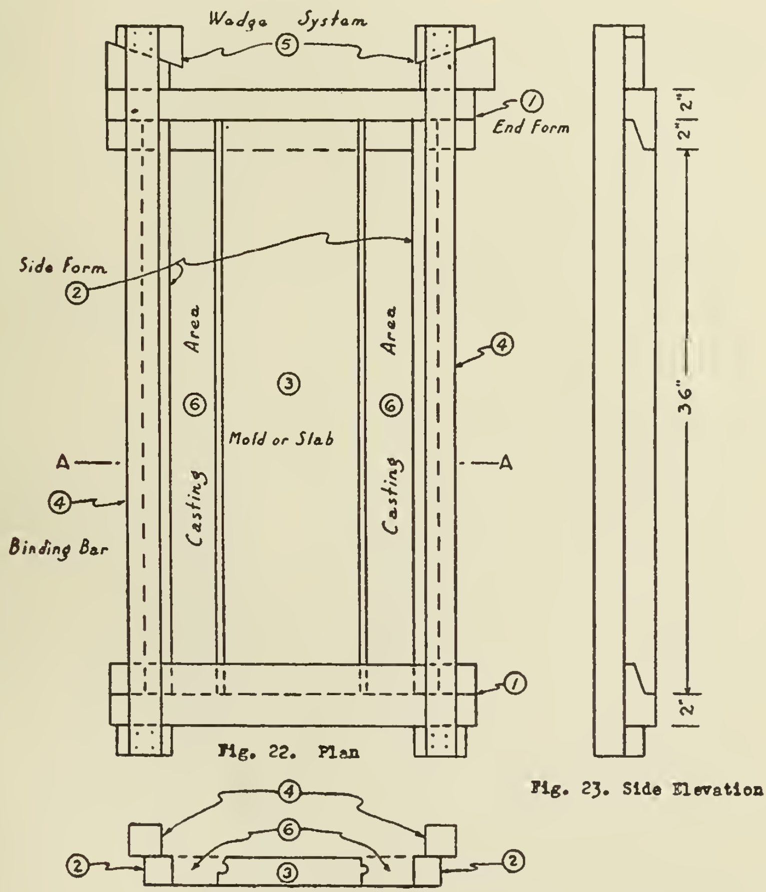


Fig. 22. Plan

Fig. 23. Side Elevation

Fig. 24. Section A - A

PRECAST CONCRETE INVERT SLABS
SIDE FORM CASTING LAYOUT
NO SCALE JULY 1941

their respective positions on a level surface, preferably a platform. After spacing the side forms approximately 3″ to 4″ from and parallel to the mold, the whole form layout is bound with the binding bars and wedges. After oiling the adjacent surfaces of the mold, side forms and end forms, the form is now filled with con-

PLATE VII

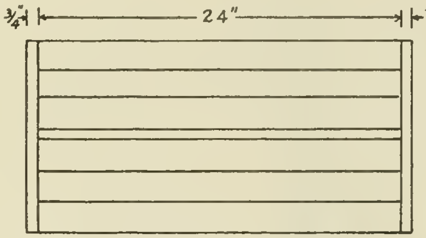


Fig. 25. Plan - 2 forms

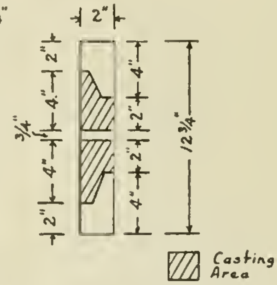


Fig. 26. End section - 2 forms

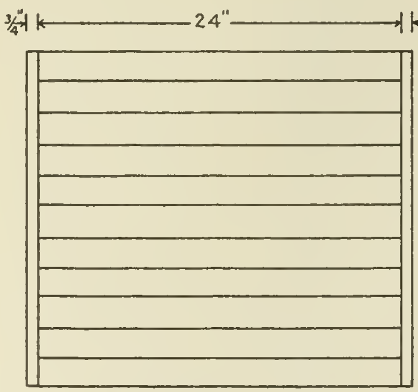


Fig. 27. Plan - 4 forms

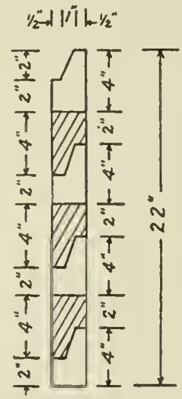


Fig. 28. End section - 4 forms

PRECAST CONCRETE INVERT SLABS
END FORM CASTING LAYOUT
NO SCALE JULY 1941

crete or cement mortar which is thoroughly tamped and struck off level with the forms and mold. The forms may be removed in 12 to 24 hours and reused. The newly poured concrete side forms should be inspected to see that no voids exist on the side and end joints and any "fins" or protuberances removed. Small voids

PLATE VIII

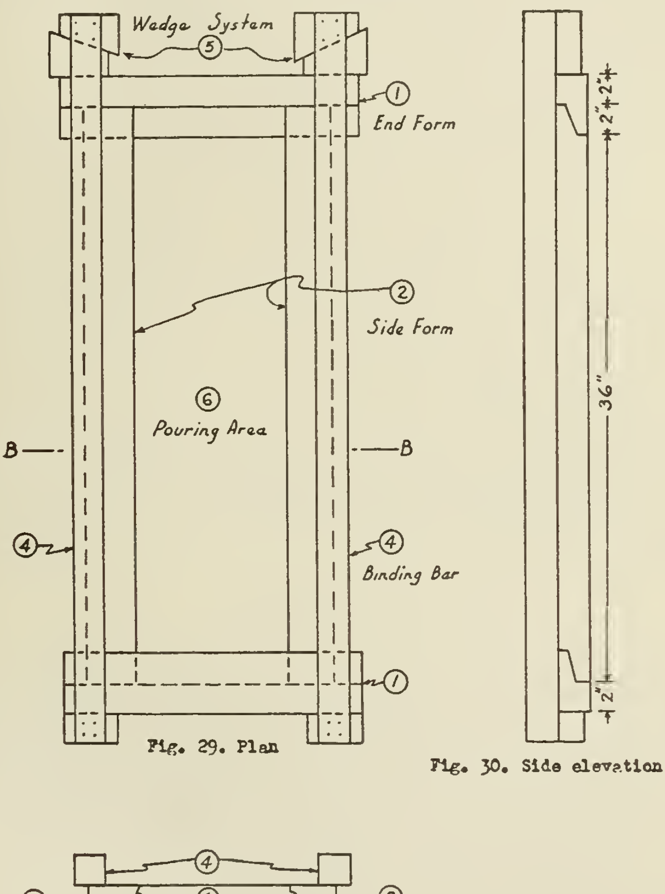


Fig. 29. Plan

Fig. 30. Side elevation

Fig. 31. Section B-B

PRECAST CONCRETE INVERT SLABS
SLAB CASTING LAYOUT
NO SCALE JULY 1941

may be filled with neat cement, bringing the joint to its true surface. The forms should be cured from 3 to 7 days unless a quick setting or very rich mix is used.

In Plate VII, Figs. 25, 26, 27, and 28, are shown two alternative end-form casting layouts. Figs. 25 and 26 illustrate end-form pouring with two end forms facing and parallel to each other. The pouring area is divided by a spacer into two sections, each of which has the required dimensions. Figs. 27 and 28 show the plan and end section for a pouring layout using four or more forms. All similar surfaces are parallel and spaced 6".

After the concrete side and end forms are fully cured they are coated with oil and assembled as shown in Plate VIII, Figs. 29, 30, and 31. The top width of the slab can be varied from a fraction of an inch to approximately 18" using 24" end forms and 3" to 4" side forms. After casting both types of side forms, that is from mold "S" and mold "C," any one of the basic or modified slabs may be poured in the width desired as the side forms are movable and interchangeable. The slabs that are cast now may be used in the place of the original wood or metal molds and the original wood end forms replaced by the concrete ones. By using quick setting cement or a very rich mix for the concrete forms and first slabs cast, the plant capacity can be rapidly enlarged. A small supply of perfectly cast slabs should be kept on hand for use in future pouring of slab forms.

Casting Costs

At Fort Benning, Georgia, the supervising officers* of the Mosquito Control Project have set up a casting plant using this system. The Georgia Department of Public Health, with the cooperation of the National Youth Administration Training Project at Chapman Springs, furnished six sets of each type mold and end form. Salvaged lumber was used for making the side forms, binding bars and wedges, and burned motor oil was used for form coating. Using a foreman and two laborers, and hand mixing the mortar and concrete materials, they have cast approximately 120 sets of "S" and "C" side and end forms. They are now casting 10" top width concrete slabs of the "C" and "S" types. They used a mix of 1 part cement to 3 parts sand for the forms and a mix

*Lieutenants Lester Bridges and S. W. Fowler.

of 1 : 2 : 4 was used for the slabs. Amounts and costs of labor per cubic yard of concrete are:

1 foreman	9 hrs. at .75 =	$6.75
2 laborers	9 hrs. at .30 =	5.40
		$12.15

These labor costs cover the complete cycle of operation; cleaning, assembling and oiling of forms, mixing and casting, and removal of slabs to the curing pile. As the plant capacity is increased and machine mixing is employed, the unit labor cost will undoubtedly be reduced. Unit labor costs for the cycle of form pouring were approximately $18.00 per cubic yard or 50% higher due to the smaller quantities produced and the necessity of training the labor.

Material costs at Fort Benning are:

Cement	$1.65 per barrel
Sand	1.40 per cu. yd.
Gravel	2.40 per cu. yd.

On that basis materials for one cubic yard of 1 : 3 cement mortar used for the forms cost:

Cement	9.7 bags	@ $\frac{1.65}{4}$ =	$4.00
Sand	29.1 cu. ft.	@ $\frac{1.40}{27}$ =	1.51
TOTAL			$5.51 per cu. yd.

Materials for 1 : 2 : 4 concrete mix used for slabs cost:

Cement	6 bags	@ $\frac{1.65}{4}$ =	$2.48
Sand	12 cu. ft.	@ $\frac{1.40}{27}$ =	0.62
Gravel	24 cu. ft.	@ $\frac{2.40}{27}$ =	2.13
TOTAL			$5.23 per cu. yd.

For one set of two end forms and two side forms for each type, labor at $18.00/cu. yd. and materials at $5.51/cu. yd., the unit costs are as shown.

1 Set of Forms	Cu. Yds. Per Set	Materials Cost	Labor Cost	Total Cost
"C"	.0166	$0.091	$0.299	$0.39
"S"	.015	0.083	0.270	0.35

Unit slab costs with labor at $12.15/cu. yd. and materials at $5.23/cu. yd. are as shown for 10" top width slab.

1 Slab	Cu. Yds Per Slab	Materials Cost	Labor Cost	Total Cost
"C"	.0175	$0.092	$0.213	$0.31
"S"	.0162	0.085	0.197	0.28

Installation

Since casting operations have not been underway long enough to begin installation and because it is planned to use larviciding labor for grading and installation during the winter months, actual figures on installation costs are not now available.

The planned method of installation is as follows:

1. Batter boards for line and grade will be set at 50′ intervals.
2. Fine grading will proceed for the width of the center slab or two center slabs and placing of the center slab or slabs will closely follow.
3. Fine grading for all sloping slabs will be checked for slope at 10′ intervals using a grading template. The sloping slabs will be placed with each slab breaking the end joints of the previously laid slabs as in brickwork.

Summary

Two types of circular joints have been designed for precast invert slabs. With these variable-angle, full bearing joints, and variable slab widths, practically any invert section may be constructed. Cost of plant installation for slab casting is greatly reduced with the use of cement mortar or concrete forms cast on the job-site. Slab casting costs are likewise minimized with these forms that are bound together with a wedging system requiring no repetitive nailing or bolting. Installation costs can be reduced by holding the slab widths to an 18″ maximum—slabs of this size can be placed by one man.

It is believed that the use of these slab and joint designs and methods of casting and installation will considerably reduce the cost of ditch lining. This should result in the extension of this malaria control practice to areas where previously the cost has been considered prohibitive.

REFERENCES CITED

1. Le Prince, J. A. and Orenstein, A. J., Mosquito Control In Panama. G. P. Putnam's Sons, New York, 1916.
2. Portland Cement Association Bulletins, No. C P 40 and No. C P 45.

THE DESIGN AND APPLICATION OF A NEW TYPE AUTOMATIC SIPHON FOR MALARIA CONTROL*

W. A. Legwen and R. S. Howard, Jr.

The introduction of siphons in malaria control practice was preceded by the use of various flushing or sluicing devices (Ross[1] and Le Prince[2]) to control mosquito-breeding in ditches or streams. Subsequently, this method was employed in Palestine, Bengal, Netherlands Indies, Malaya,[3] and the Philippines.[4]

Devices used to flush ditches or streams have been of many types; their function was to store water temporarily and to release suddenly a charge downstream in excess of the normal flow. Included among such devices were hand-operated wooden or metal gates, tipping buckets, boxes or drums, box sluices and wall sluices. In recent years, a number of workers have experimented with different designs of automatic siphons, with varying degrees of success.

In 1936, Williamson and Scharff[3] made a study of the materials and devices used in obtaining periodic and automatic flushing, and its efficiency in anopheline control. In this report is found the first reference to an automatic siphon (de Villier's) with no moving parts, the principle of which was used by MacDonald[5] in the design of the automatic siphon which bears his name and is considered to be the most satisfactory to date. In essence, this consists of reducing the atmospheric pressure within the siphon chamber by exhausting the air contents with suction created by a flow of water through a small-diameter pipe. From this it is seen that a waste of water prior to siphonage is necessary. This suggests that during the very low flows an equilibrium may be established between the inflow and this waste water discharged. In such cases the siphon would not operate.

D. B. Blacklock,[6] in 1939, reviewed the literature and conducted many tests on siphons with special reference to anti-mosquito work. Of those tested, MacDonald's appeared best but even that type failed to prevent flow-through or waste and Blacklock stated

---

*From the Division of Public Health Engineering and the Division of Malaria and Hookworm Service, Georgia Department of Public Health, Atlanta, Georgia. The authors desire to acknowledge their indebtedness to Mr. B. H. Bell, Sumter County Health Engineer, Americus, Georgia, the National Youth Administration of Atlanta, Georgia, for making models, and Mr. J. O. Davis, Augusta, Georgia, for aid in conducting tests on experimental siphon models.

". . . the difficulty was to discover some means by which preliminary loss of water before siphonage commenced could be avoided, so that full advantage could be taken of very small rates of flow in streams." The one feature common to all the siphons studied by him was that their actuation depends upon gradual evacuation of

PLATE I

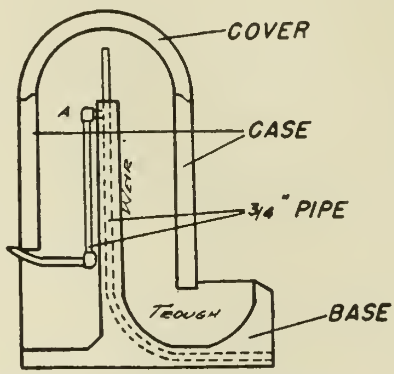


FIG. 2. MACDONALD SIPHON

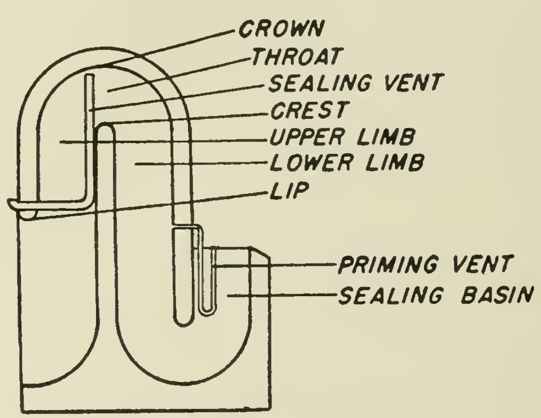


FIG. 3. LEGWEN-HOWARD SIPHON

air, brought about by water flowing through the siphon. The amount of water necessary for this is very difficult to compute and, in most siphons, will result in an equilibrium at some definite rates of inflow.

There is no record of siphonage in anti-mosquito work in this country. The study of siphons in Georgia was begun by one of the authors (WAL) in 1938 in connection with county-wide malaria control in Richmond County. At that time, it was desired to fluctuate the water level in ponds not amenable to drainage control in order to reduce breeding of *A. quadrimaculatus*. [This mosquito, generally a pond breeder, has been observed breeding in ditches and streams with no flow or with a very sluggish current.]

The subject siphon has been designed to fluctuate water levels of ponds and to flush ditches or streams. It is of the inverted U-type, similar in outward appearance to the MacDonald siphon; in detail, however, there are differences as shown in the illustrations of Plate I.

The wall of the lower side extends into the sealing basin to a depth slightly greater than the depth of throat. A 1/4" U-tube, or priming vent, is set into the downstream wall opening into the lower limb above the level of the sealing basin; the other end is set at the water level in the sealing basin. The low point of the priming vent is slightly above the lower lip. On the upstream side of the siphon, about 1" above the upper lip, is attached a sealing and breaking vent made of 3/4" pipe which extends through the wall and into the siphon chamber, rising to a point within 1/2" of the crown.

For the initial operation, (see Plate II, Figs. 4, 5, 6.) it is necessary that the sealing basin be completely filled and the priming vent on the lower side filled to the height of the sealing basin. During the filling of the reservoir, the water levels in the reservoir and in the upper limb remain equal until the rising water reaches the sealing vent. At that instant, the air within the siphon is equal in pressure to that outside the siphon and the air inside is sealed at both inlet and outlet. As the water continues to rise, regardless of the rate, the water level within the upper limb of the siphon lags below that outside. This lag, which is measurable and computable, is due to the compression of the entrapped air and displacement of water in the lower limb. The pressure on the entrapped air (a gas) being equal at all points, the difference between the water levels in the upper limb of the siphon and in the reservoir must be equal to the difference in the level of the water in the lower limb of the siphon and that of the sealing basin. The depth of water in the

upper limb, as measured from the elevation of the sealing point of the upper vent, is slightly greater than the above-mentioned difference since the air has been compressed by the pressure head and this change in volume must be taken up by the rise of water in the upper limb of the siphon. As the water continues to rise, the lag

PLATE II

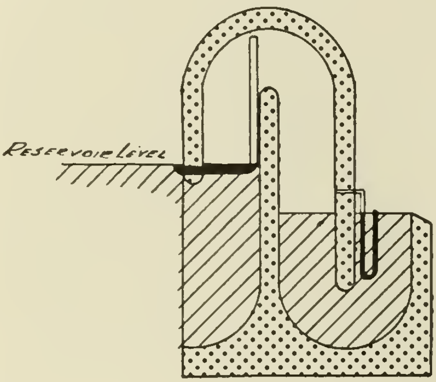


FIG. 4.

SEALING STAGE

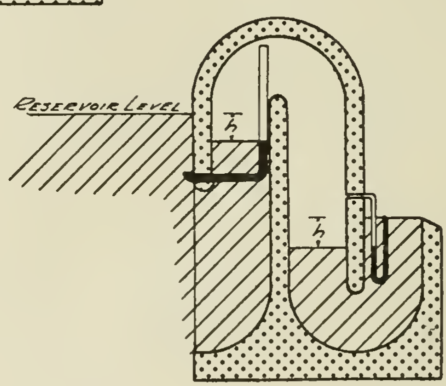


FIG. 5.

INTERMEDIATE STAGE

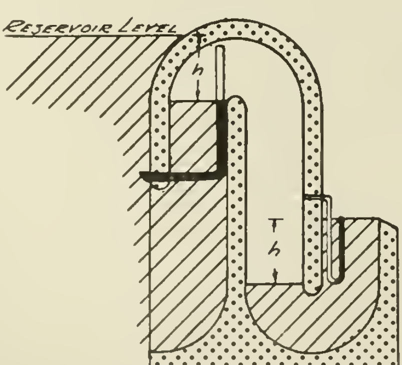


FIG. 6.

IMMEDIATELY PRIOR
TO DISCHARGE STAGE

or head increases but continues to be the same amount on the upper and lower sides of the siphon. On the lower side, as the water is driven down in the lower limb, it is also driven down in the priming vent. Immediately prior to discharge, the water level in the reservoir, or upper pool is slightly above the inside crown of the siphon. The water level in the upper limb should be slightly below but in no case equaling or exceeding the elevation of the crest of the siphon; the water level in the lower limb has been lowered until it is equal with the lowest point of the inside of the priming vent. The water in the priming vent has been driven down to the same level and any further rise of water level in the reservoir results in an increase in pressure of the entrapped air. This forces the air around the bend in the priming vent where it rises and drives out the column of water in the vent. This break of the water seal in the priming vent results in the rapid release of air from the siphon, restoring the air pressure therein to atmospheric pressure. In turn, the water in the upper limb attempts to equalize its elevation with that of the reservoir level. When this occurs the flow develops and within 60 seconds complete siphonic action has been established due to the rapid evacuation of air by a full flow of water through the upper limb and throat.

The siphonic action continues until the water level in the reservoir is drawn down to such a point that all the water in the sealing vent is forced upwards through the throat of the siphon, admitting air rapidly and completely breaking the siphonic flow. This breaking point is at an elevation slightly below the lowest portion of the sealing vent. The admission of air restores the air pressure in the siphon to atmospheric pressure and the cycle of operation is completed, leaving the sealing basin and the priming vent on the lower side filled so that subsequent operation of the siphon is automatic.

From this description of action it is obvious that, until the release of air takes place through the priming vent, there is no flow from the upper to the lower pool and the only water leaving the siphon is that displaced in the lower limb; consequently, as long as the inflow of water to the reservoir is sufficient to overcome evaporation and transpiration, the siphon will operate automatically at the desired or calculated reservoir level.

It will be noted also that, after sealing, the water level in the upper limb of the siphon is always below that of the reservoir water level. When flow begins it is because of a positive pressure head and is not the result of a partial vacuum. In practice the time from

release of air to attainment of full siphonic flow is less than one minute for a siphon with inside dimensions of approximately 6" x 18".

[A mathematical formula for designing or checking this type siphon is shown on Plate III, Fig. 7.]

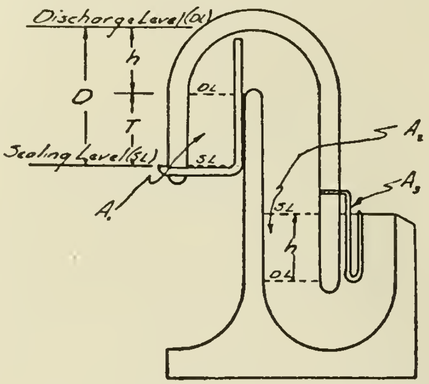


FIG. 7. VERTICAL SECTION

PLATE III

V_1 = Volume of entrapped air at sealing time.

P_1 = Pressure of entrapped air at sealing time = atmosphere pressure.

V_2 = Volume of entrapped air at time of discharge.

P_2 = Pressure of entrapped air at time of discharge (in lbs/sq.in.)

A_1, A_2, A_3 = Cross sectional area of siphon or pipes at designated points.

h = Head of water upon entrapped air, in inches.

T = Depth of water from sealing line to level in upper limb, in inches.

$P_2 = P_1 + (h \times \frac{.433}{12})$ (wt. of 1 column of water = .433 lbs/sq.in.)

$P_2 = 14.7 + .036h$

$P_1 V_1 = P_2 V_2 \qquad V_2 = \frac{14.7V_1}{14.7 + .036h}$

Contraction of air $= V_1 - V_2 = V_1 - \frac{14.7V_1}{14.7 + .036h} = V_1 - \frac{V_1}{1 + .0025h}$

V_3 = Volume of water displaced by air in lower limb and vent $= h(A_2 + A_3)$

V_4 = Volume of air displaced by water in upper limb $= V_3 + (V_1 - V_2) =$
$h(A_2 + A_3) + (V_1 - V_2)$

$T = V_4 \div (A_1) = \frac{h(A_2 + A_3) + (V_1 - V_2)}{A_1} = \frac{h(A_2 + A_3) + (V_1 - \frac{V_1}{1 + .0025h})}{A_1}$

$D = h + T$

$D = h + \frac{h(A_2 + A_3) + V_1 - \frac{V_1}{1 + .0025h}}{A_1}$

Application to Mosquito Control

Dr. Henry R. Carter,[7] in 1914, observed the advantages of water-level fluctuation in controlling anopheline breeding. Writing of his experiences on mill ponds in North Carolina, he stated, "These changes of elevation within a shorter time than the cycle of development of the mosquito should tend to prevent breeding. As the water falls it should leave some larvae stranded in the grass and behind drift, while the rise would expose them to some extent to fish, from which the shallow water and other conditions at the edges had protected them." Carter, Le Prince and Griffitts,[8] in 1916, reported upon studies of water level fluctuation as an anti-anopheline practice.

Hinman,[9] in 1938, described the biological effects of water-level fluctuation on anopheline breeding. The same author,[10] in 1940, reported on the cyclical and seasonal fluctuation practiced on the lakes of the Tennessee Valley Authority. Water-level fluctuation is an important part of the malaria control program of the Authority; this practice has been used to control anopheline breeding and to minimize growths of certain objectionable plant species that occur in the zone of fluctuation.

Experience with the water-level fluctuation has indicated that a change in water level of approximately one foot, within or in less than the time for the developmental cycle, egg to adult, is effective in controlling anophelines. The authors feel, therefore, that the subject siphon has application as a device for fluctuating the water level of ponds and lakes in addition to its use as a flushing mechanism. In some impoundments, siphons may be used to fluctuate the water level in the reservoir and also to flush the outlet below the dam. Though siphons have been used on power dams to function as spillways, water management on hydro-electric impoundments involves procedures that make their use impractical in fluctuating pool-levels for anopheline control. Nevertheless, there are numerous fish-ponds, recreational lakes, swamps, etc., in which automatic siphonage may be used advantageously as a fluctuating mechanism with probable mosquito-control benefits.

In the use of automatic siphons for fluctuation there are several important factors to determine prior to installation. First, there must be sufficient inflow to raise the water level of the pond or reservoir to the required elevation in less time than is required for the developmental cycle of the mosquito. Second, the capacity of the siphon must be great enough so that the period required for

filling and discharge (complete cycle of fluctuation) is less than the aquatic cycle of the insect. This requirement may be be stated in another way: the sum of the filling time and drawing time must be less than the mosquito cycle.. Mathematically, the daily capacity of the siphon is equal to the sum of the filling time and drawing

PLATE IV

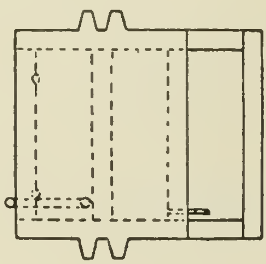


FIG. 8. PLAN

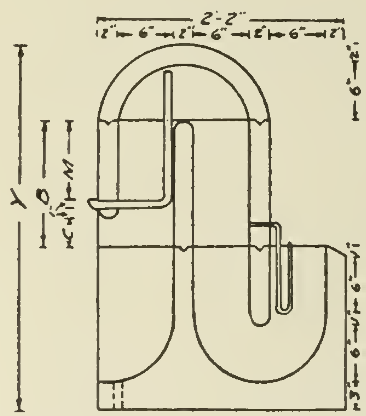


FIG. 9. VERTICAL SECTION

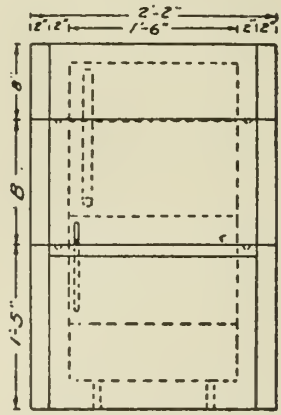


FIG. 10. DOWNSTREAM ELEVATION

VARIABLE SIPHON DIMENSIONS

MIN. HEAD	MAX. HEAD	FLUCT. DEPTH	HEIGHT "Y"	"B"	"C"	"M"
4"	19½"	15½"	38½"	13½"	3"	8½"
12"	27¾"	15¾"	46¾"	21¾"	11"	8¾"
24"	40"	16"	59"	34"	23"	9"
36"	52¼"	16¼"	71¼"	46¼"	35"	9¼"
48"	64½"	16½"	83½"	58½"	47"	9½"

time, multiplied by the normal flow and divided by the drawing time; or, the ratio of capacity to daily inflow is equal to the sum of the filling time and drawing time, divided by the drawing time.

A series of tests has been run on a siphon with a water-channel cross-sectional area of 108 square inches. This siphon is

PLATE V

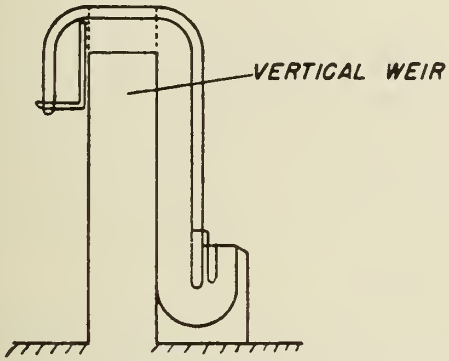


FIG. 11. SIPHON INSTALLATION IN EXISTING SPILLWAY (VERTICAL SECTION)

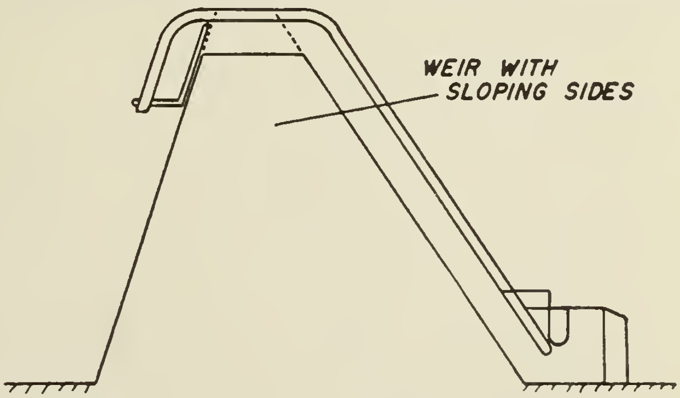


FIG. 12. SIPHON INSTALLATION IN EXISTING SPILLWAY (VERTICAL SECTION)

similar to the design shown on Plate III and is constructed of galvanized metal. It discharges 525, 650 and 775 gallons per minute at heads of 10, 15 and 20 inches respectively. It is possible to increase the capacity of this type siphon without appreciably changing the depth of drawdown of fluctuation by either increasing the width of the siphon throat or by increasing the head. The latter is shown by the figures and table on Plate IV. More than one siphon may be installed in a single dam to furnish greater discharge; in this case, two or more siphons must be connected with a common venting system.

This siphon may be of precast construction similar to that employed with the MacDonald siphon or it may be poured in place in existing dams (Plate V. Figs. 11 and 12). This device may be used to control mosquito breeding in ditches or streams in the manner of the MacDonald siphon.

Thus far, no observations have been made on its efficiency in controlling anopheline breeding either above or below dams.

Summary

A new type automatic siphon has been described and its application in *Anopheles* control by fluctuation and flushing has been discussed. The advantages of this siphon are (1) automatic operation with no preliminary waste of water, (2) simplicity of construction and installation, and (3) positive sealing and breaking.

REFERENCES CITED

1. BOYCE, R. Mosquito or Man? London.
2. Le PRINCE, J. A., and ORENSTEIN, A. J. Mosquito Control in Panama. New York: G. P. Putnam's Sons, 1916.
3. WILLIAMSON, K. B., and SCHARFF, J. W. Anti-Larval Sluicing. Malayan Med. Jl., 2: 124-150, September, 1936.
4. RUSSELL, P. F. The control of *A. minimus* mosquito larvae by stranding and flushing. Philippine Jl. Sci., 47: 439-447, April, 1939.
5. MacDONALD, G. A design of flushing siphon for control of Anopheline breeding. Jl. Mal. Inst. India, 2: 63-69, March, 1939.
6. BLACKLOCK, D. B. Notes on siphon action with special reference to anti-mosquito work. Ann. Trop. Med. and Parasit. 33: 141-160, July, 1939.
7. CARTER, H. R. Impounded Water: some general considerations of its effect on the prevalence of malaria. Public Health Reports, 29: 3458-4368, December 25, 1914.
8. CARTER, H. R. Le PRINCE, J. A. and GRIFFITTS, T. H. D. 1916 Impounded Waters. Surveys in Alabama and South Carolina During 1915 to Determine Its Effect on Prevalence of Malaria. Public Health Bulletin, Wash. 79:34.
9. HINMAN, E. H. 1938. Biological effects of fluctuation of water level on anopheline breeding. Amer. Jl. Trop. Med. 18: 483.
10. HINMAN, E. H. 1941. Human Malaria. p. 327. The Science Press.

STUDIES ON ARTIFICIAL RESTING PLACES OF *ANOPHELES QUADRIMACULATUS* SAY*

Melvin H. Goodwin, Jr.

The need for improved means of qualitative and quantitative measures of anophelism is appreciated by all who have occasion to appraise malaria situations or to evaluate anti-mosquito malaria-control measures. The problems concerned with making such measurements vary with species and localities. Especially informative accounts of the difficulties of collecting anopheline adults have been presented by Russell[3] and Strickland and Roy[4]. In contrast to the conditions described for tropical species, the day-time resting places of *Anopheles quadrimaculatus* are usually found without difficulty. Boyd[1] has listed several types of natural, diurnal resting-places for this species including dwellings, animal houses, tree holes, culverts, etc. These have the undisputed advantage of natural attractiveness and some of them harbor tremendous numbers of anophelines. The chief objections to them are: (1) that complete collections, even from parts of them, cannot always be made or are so time-consuming as to be impractical and (2) their lack of physical comparability from station to station. By using carefully planned and regulated enumerative procedures that repeatedly sample mosquito populations in natural resting places under the same circumstances, reliable time comparisons of adult densities can probably be made. Space comparisons by this procedure are more difficult, less dependable and are frequently impossible.

Accordingly, devices that are intrinsically comparable such as animal-baited traps, light traps, and artificial resting-places have been used in determining relative variations in mosquito densities under different conditions or in different situations. Of these, the most feasible to date, as far as *A. quadrimaculatus* is concerned, appears to be the nail-keg artificial resting-place[5] developed in the Tennessee Valley. These were installed in a variety of situations in south Georgia and the adult counts compared with those in natural

*Contribution from the Emory University Field Station, Newton, Georgia. The author desires to acknowledge his indebtedness to Dr. Justin Andrews, Director of the Emory University Field Station, for helpful suggestions and criticisms, and to Mr. Robert Lofton, who supervised construction and installation of all devices used in making these observations.

resting places. In this section the comparison was not favorable nor did the nail keg attract large enough numbers of adults to furnish reliable estimates of adult populations. Efforts were made, therefore, to see whether or not the general principle of the small, portable resting-place, as embodied in the nail-keg, might be adapted to give better results locally. It was recognized at the outset that the probability of developing an artificial resting place as attractive to anophelines as natural resting-places was not likely. Nevertheless, it was considered important to find one that would adequately sample the population while retaining such characteristics as durability, portability, use indoors and out-of-doors and, most of all, uniformity from physical standpoint.

Materials and Methods

Boxes of various sizes and shapes were constructed of 1" x 4" tongue-and-grooved, dressed pine stock, painted inside and out either with lamp black in neutral mineral spirits or with colored enamel.

These boxes were located ordinarily in the shade near *A. quadrimaculatus* breeding places. Some were placed on the ground; others were nailed to trees or stakes at various indicated heights or were set on racks or shelves so that their arrangement could be readily varied.

As a rule, the boxes were examined for mosquitoes daily though no evidence of substantial accumulation of adults from day to day was ever obtained when counts were made at longer intervals. Anophelines were counted by species and, in many cases, by sex and then collected alive with a suction tube. The data on sex and species distribution are reserved for a future report.

Total counts of *A. quadrimaculatus* were treated by the usual statistical methods and are shown as averages with probable errors. Difference between means as great as three probable errors were considered significant.

Results and Discussion

1. *Effect of size.* Preliminary observations with boxes more than two feet in length or over one square foot in cross-section indicated that the larger sizes served no useful purpose from the standpoint of attracting more *A. quadrimaculatus* adults, were cumbersome to handle, and made collecting more difficult. Accordingly,

they were abandoned and no experimental determinations were made with them.

Four sizes of rectangular boxes, open at one end, were made with the following dimensions in inches: 6 x 6 x 12, 6 x 6 x 24, 12 x 12 x 12, and 12 x 12 x 24. The mean daily counts of *A. quadrimaculatus* made in these boxes in three different locations are shown in Table I. In all locations, the average catch was greater

Table I

ADULT *A. QUADRIMACULATUS*-COUNTS IN BOXES OF DIFFERENT SIZES AND IN DIFFERENT POSITIONS

Location Number	Relative Position	Number of Counts	Average counts in boxes of following dimensions in inches			
			12x12x12	6x6x12	12x12x24	6x6x24
1	Unchanged	20	4.75±0.47	0.15±0.05	2.30±0.35	0.40±0.15
2	Unchanged	20	7.05±1.02	0.20±0.06	1.25±0.24	0.80±0.18
3*	1	6	31.50±4.34	5.33±0.97	36.00±5.66	8.50±1.13
	2	6	23.33±2.95	4.67±0.26	26.83±2.86	9.50±1.30
	3	6	27.33±3.32	6.33±1.80	29.33±2.59	6.83±0.89
	4	6	27.67±3.32	9.00±0.95	30.17±3.75	8.00±1.30
	Subtotal (Location 3)	24	27.46±1.81	6.33±0.61	30.58±2.00	8.21±0.57
	TOTAL	64	13.98±1.17	2.48±0.34	12.57±1.40	3.45±0.38

*Boxes at this position were arranged to include all possible combinations so that each box occupied each position six times.

in the boxes with the 12 x 12 inch opening and, in the first two, there was a decided preference for the box 12 inches deep rather than the one 24 inches in depth. Subsequent observations, however, indicated that there was no significant statistical difference between the counts in these two boxes; in fact, there was a small numerical superiority in the number of adults seeking shelter in the deeper one.

At the third location, the arrangement of boxes was changed after each collection, so that each box occupied each position six times, to see whether or not relative positions of any one of the boxes attracted more anophelines. No statistically valid differences were found among the average counts in various positions.

2. *Effect of height above ground.* Since the one-foot-square box proved to possess advantages over the others, it was subjected to certain tests to assist in selecting desirable catching locations. Single boxes were placed in situations comparable except for dif-

ferences in height. As shown in Table II (Locations 1, 2 and 3) there was no decided preference as far as height was concerned.

Table II

ADULT *A. QUADRIMACULATUS*-COUNTS IN BOXES AT DIFFERENT HEIGHTS

Location Number	Number of Counts	Average counts in boxes at the following heights in feet above ground					
		0	1.5	4.5	3.0	6.0	7.5
1	20	—	9.65±1.35	6.95±1.05	10.10±1.54	4.75±0.47	—
2	10	8.00±0.09	—	1.17±0.48	10.00±0.00	8.75±1.38	—
3	15	16.85±1.70	—	21.73±2.76	—	17.00±3.03	7.00±0.79
4*	35	26.51±1.39	15.94±1.29	9.51±0.68	5.26±0.48	5.71±0.52	4.11±0.47

*Boxes at this location arranged in vertical tier.

These shelters were then arranged in vertical tiers so that a definite choice of shelters at different heights could be made by the mosquitoes. The results indicated in Table II (Location 4), show significantly larger counts in the boxes within three feet of the ground.

3. *Effect of direction in which boxes faced.* To determine whether or not there was a preference for shelters facing breeding places, source of blood-meals, compass directions, prevailing winds, etc., banks of four boxes were set up three feet above ground with the openings in different directions 90° apart. Table III summarizes the information obtained. At the four sites selected, whether located near or at a distance from or facing breeding areas or dwellings, no significant difference in average daily counts was observed as far as direction was concerned, though it is interesting to note that the boxes facing east, i. e. the direction of the rising sun, regularly had lower counts than those facing the other directions.

Table III

ADULT *A. QUADRIMACULATUS*-COUNTS IN BOXES FACING DIFFERENT DIRECTIONS

Location Number	Number of Counts	Average counts in boxes facing the following directions			
		North	South	East	West
1	10	12.10±2.17	9.80±0.90	7.20±0.59	13.10±1.68
2	20	9.95±1.29	10.20±1.54	6.95±1.11	9.35±0.68
3	20	4.75±0.47	7.00±1.02	4.45±0.50	4.20±0.52
4	33	13.12±1.11	13.09±1.18	11.88±0.79	13.15±0.96
TOTAL	83	10.22±0.66	10.14±0.67	8.34±0.49	10.07±0.55

4. *Effect of offering choice of boxes horizontally arranged.* As it was intended to set up multiple-choice color experiments (see below), it was first determined whether or not *A. quadrimaculatus* adults would enter in random fashion, boxes that were arranged in a horizontal row. Counts were made for 38 days in a series of eight boxes about three feet above ground. As shown in Table IV

Table IV

ADULT *A. QUADRIMACULATUS*-COUNTS IN BOXES HORIZONTALLY ARRANGED

Location Number	Number of Counts	Average counts in boxes horizontally arranged (left to right)							
		1	2	3	4	5	6	7	8
1	38	37.32 ±3.96	18.61 ±2.22	13.74 ±1.31	6.74 ±0.70	7.82 ±0.62	9.08 ±0.82	11.97 ±0.88	23.34 ±1.48
2	15	26.20 ±3.23	10.07 ±0.89	8.00 ±0.81	7.60 ±1.09	14.87 ±1.31	—	—	—

(Location 1) the average counts in the boxes at either end were greater than those towards the middle. When the end boxes were closed, the counts were higher in the boxes next to the end and so on down to three boxes. The same apparent preference was observed with a five-box series (Table IV, Location 2). Thus it was evident that in any comparisons involving counts of adult anophelines made in a series of boxes arranged horizontally, the boxes would have to be shifted daily to minimize the effect of position relative to the ends of the series.

5. *Effect of different colored boxes.* One difficulty attending the use of the black boxes was the necessity of using a flash-light to be able to see and count the mosquitoes. When the light was turned on, the mosquitoes often became active and required some time to resume a resting position; a few usually escaped. It seemed apparent that a lighter-colored box, if as attractive as the black, might prove a solution to this problem. Nuttall and Shipley[2] have shown that certain blue and red colors are preferred to black by anophelines. Accordingly, two series of various colored boxes, arranged in horizontal rows about three feet above ground, were placed near breeding places. These boxes were painted on the inside with colored enamel and on the outside with lamp black as previously described. They were rearranged each day to prevent pref-

erence due to position. Results obtained are presented in Table V from which it is quite evident (1) that the average daily counts in the red and black boxes are significantly higher than those in the

Table V

ADULT *A. QUADRIMACULATUS*-COUNTS IN BOXES OF DIFFERENT COLORS

Location Number	Number of Counts	Average counts in boxes of the following colors					
		White	Yellow	Red	Blue	Black	Green
1	30	0.03±0.02	0.37±0.10	31.43±2.89	0.10±0.04	15.33±1.30	0.60±0.17
2	17	0.06±0.04	0.12±0.08	11.24±1.09	1.00±0.23	8.29±1.10	0.24±0.07
TOTAL	47	0.04±0.02	0.28±0.07	24.13±2.11	0.43±0.02	12.79±0.99	0.47±0.11

other boxes and (2) that the red boxes attracted more *A. quadrimaculatus* than the black ones. Inasmuch as the mosquitoes are easily seen in a red box in normal daylight without the use of the flashlight, this constitutes a real advantage in mosquito-population sampling activities.

6. *Comparison of red boxes, block boxes, nail kegs and natural resting places.* In view of the apparent superiority of the red boxes these were compared with black boxes, nail kegs and, in some instances, with natural resting places at various locations in south

Table VI

ADULT *A. QUADRIMACULATUS*-COUNTS IN VARIOUS RESTING PLACES

Location Number	Number of observations	Average counts in following types of shelter			
		Natural resting-places*	Nail keg	Red box	Black box
1	13	6.31± 0.83	—	—	1.23±0.22
2	14	8.58± 1.15	—	—	13.21±1.29
3	13	18.00± 1.72	—	—	18.15±2.36
4	13	78.67±16.29	—	—	21.62±2.63
5	16	—	6.13±0.88	16.06±1.54	13.75±1.27
6	17	—	7.82±0.81	22.82±2.19	26.41±2.67
7	3	—	7.00±1.39	20.33±8.50	11.00±1.93
8	3	166.00±39.51	—	21.33±2.57	13.67±2.12
9	3	—	—	11.00±2.29	10.67±3.79
10	3	—	5.00±1.10	20.67±5.36	17.00±4.41
11	3	54.66±13.76	—	12.33±6.25	5.66±2.12
12	3	27.75± 3.22	8.00±0.94	11.25±0.97	—
13	3	13.75± 4.09	—	11.50±1.30	—
14	2	1.00± 0.00	1.00±0.48	2.00±0.00	2.50±1.19
15	3	48.00± 1.63	—	4.00±0.64	—

*Outbuildings (animal shelters, feed cribs, privies, implement sheds, etc), culverts and hollow trees.

Georgia. The average counts from these miscellaneous observations for various lengths of time are shown in Table VI*. It is obvious that, in general, the red boxes attracted more mosquitoes than the black, that the average counts in either of these were greater than in nail kegs and that, as was to be expected, fewer anophelines were found in artificial resting places than were found in natural shelters.

Summary

A box-type artificial resting place is described which, in Georgia, seems to attract more *A. quadrimaculatus* adults than do other types.

It consisted of a 12-inch wooden, cubical box, open at one end, painted either black or red inside and out. Counts were higher in the red boxes and the mosquitoes were easier to see than in the black boxes.

Single boxes within six feet of the ground seemed equally attractive but when vertical tiers of boxes were made available, a preference for those within three feet of the ground was exhibited.

When offered the opportunity of selecting boxes arranged horizontally at the same height, *A. quadrimaculatus* tended to go into the boxes at the ends of the row.

When boxes on the same level were faced in the four compass directions, no significant preference was shown for any one box, irrespective of whether they were located near or at a distance from or facing breeding areas, or blood-meal sources.

References Cited

[1]Boyd, Mark F.: An introduction to malariology. Harvard University Press, 1930 pp. 437.

[2]Nuttall, G. H. F., and Shipley, A. E.: Studies in relation to malaria. II, The structure and biology of anopheles. Amer. Jour. Hyg., 1902, 2: 58-84.

[3]Russell, Paul F.: Daytime resting places of anopheles mosquitoes in the Philippines. Phil. Jour. of Sci., 1931, 46: 639-649.

[4]Strickland, C., and Roy, D. N.: The prevalence and habits of anophelines in relation to physical conditions. Riv. di malarialogia, 1936, 15: 171-186.

[5]Tennessee Valley Authority, Fifth Annual Report Board of Malaria Consultants, 1939.

---

*Certain of the data included in this table were collected by Mr. R. E. Bellamy, Biologist, Division of Malaria and Hookworm Service, Georgia Department of Public Health, who kindly made them available for this report.

STUDIES ON THE CHOICE OF A MEDIUM FOR OVIPOSITION BY *ANOPHELES QUADRIMACULATUS* SAY*

Horace O. Lund

INTRODUCTION

It is reasonable to postulate that the non-occurrence of larvae of *Anopheles quadrimaculatus* Say in any particular body of water may be due either to the failure of the larvae to survive there or to the failure or refusal of adult female mosquitoes to deposit their eggs in that particular habitat. This paper is a report of an investigation of the second possibility, in which an attempt was made to determine whether wild-caught adult females, kept in laboratory cages, will exhibit preferences for some kinds of media over others for oviposition. It is conceivable that knowledge on this point might lead to the development of repellant treatments for ponds, or to the development of attractants which would localize breeding and hence increase the efficiency of larviciding operations.

Bates (1940) has pointed out that compartively few studies have been made of the nature of the media selected for oviposition by anopheline mosquitoes generally and, to the writer's knowledge, no studies of this sort have been made, previous to this one, on *A. quadrimaculatus*. It is hoped that this work, essentially preliminary as it is, may be continued in the near future.

METHODS

Wild-caught females were brought into the laboratory and placed in cages. For the first nine experiments, a large screen cage 3′ x 3′ x 2½′ was used, but this was abandoned for the rest of the experiments in favor of a more convenient size, 24 inches deep, 18 inches wide, and 18 inches high. The top and two sides were of wire screen, the front was an ample cheescloth sleeve dyed blue in color, and the back and bottom were of wood and painted blue. The bottom was covered with about an inch of wet, gray sand, and a cotton wad soaked in 10% sugar solution was hung in the screen side of each cage.

---

*Contribution from the Emory University Field Station, Newton, Ga.

For a short time each afternoon a rabbit, a portion of her side and hip closely clipped, was fastened securely to a wooden tray and placed in each cage to provide blood meals for the mosquitoes. Two

Fig. 1—Cage and dishes used in most of the experiments.

Fig. 2—Rabbit fastened on tray.

or three times each week, 15-40 new wild-caught females were added to each cage. The population in each cage probably varied from about 40-100 or more in the course of the experiments.

No attempt was made to control either temperature or humidity. The sunset-to-sunrise temperatures, however, probably ranged

from about 80° to 90° F., and the humidity was fairly high, probably from about 70% to 95% R. H. Except when dim light was purposely provided continuously throughout the night, the shades in the laboratory were drawn and oviposition took place in complete darkness.

In the first nine experiments, the media to be tested for their attractiveness or otherwise to ovipositing adults were placed in 8-inch stoneware pans. Since, however, it was found desirable to be able to control the color of the background against which the eggs were laid and, later, counted, these pans were replaced with glass culture dishes four inches in diameter. These dishes were numbered with a glass-marking crayon and covered on the bottom and sides with an elastic-topped black sateen bag. They were from one-half to two-thirds filled with 150 to 200 cc. of the test solutions. Their arrangement was reversed each day to minimize the position factor. Twelve dishes were placed in each small cage in three rows of four, the six odd-numbered dishes, containing one medium, being alternated with the six even-numbered dishes containing the contrasted medium.

Most of the experiments were run simultaneously in two cages on two successive nights, thus providing four replicates of each set of conditions.

The eggs were counted each day. In so doing, the black sateen cover of each dish was removed and the glass dish itself was placed on a white paper in good light. The black eggs were then readily discernible against the white background. They were removed on bits of filter paper and counted under a binocular dissecting microscope. When the nature of the medium prevented the eggs from turning a normal black, the dishes were examined against a black background and the eggs removed with dark papers.

In the course of these studies, over a hundred thousand eggs were removed from the dishes and counted during the months of June, July, and August, 1941.

RESULTS AND DISCUSSION

1. Chance distribution of eggs in experimental dishes under uniform conditions.

To arrive at some idea of the nature of the distribution of the eggs when the medium was the same in all the containers, six preliminary experiments were run in which all the dishes contained well water. (Table I-A).

In none of the experiments was there a statistically significant difference between the odd- and even-numbered dishes. The large standard deviations as compared with the means indicate, of course, great irregularity in the number of eggs laid in the various dishes, but no consistent pattern-arrangement of favored dishes (due to position or other uncontrolled factors) could be found. The technique would appear to be valid, therefore, provided an adequate number of trials of each variable is made.

TABLE I.

Chance distribution and effect of light on numbers of eggs (averages and standard deviations shown) laid by wild *A. quadrimaculatus* in cages.

Tests	Experiment Number											
	1		2		3		4		5		6	
	Ave.	S.D.	Ave.	S.D.	Ave.	S.D.	Ave.	S.D.	Ave.	S.D.	Ave.	S.D.
A. Chance distribution												
1. Odd dishes	62.3	53.1	59.5	83.7	60.2	30.6	168.2	55.4	69.3	26.8	59.5	37.4
2. Even dishes	77.0	94.1	75.2	54.9	110.5	69.0	142.3	45.1	79.3	31.8	32.2	14.6
B. Light effect												
1. Dim light												
Dark dishes	45.0*	47.5	30.8	24.2	104.5	171.9	116.0	69.3				
Light dishes	1.5	—	12.3	17.4	0.8	—	0	0				
2. Total darkness												
Dark dishes	62.7*	37.1	96.2*	50.6	226.5*	89.4	143.3	63.6				
Light dishes	75.2	57.2	64.7	44.8	295.7	348.5	110.8	43.6				

* Only four dark and four light pans in this experiment.

In a single experiment, in which one female only was placed in a cage and left for seven days, a few eggs at least (min.=3, max.= 142, ave. = 26.4) were laid in each dish. This suggests that each female may come in contact with several dishes during the laying process and thus provide herself an opportunity to select a particular dish.

II. *Preference for light or dark background for oviposition.*

Bates (1940) found that the females of *Anopheles atroparvus,* in dim light, seemed to prefer to oviposit in pans in which the water surface was provided with a background of black cloth or filter paper. In our first experiments, it was decided to test this preference in *Anopheles quadrimaculatus* by using the stoneware pans mentioned under "Methods." Four of the eight pans were covered on the inside with a black lacquer, the remaining four being

left their original cream color. Later on, due to the difficulty in counting the black eggs against the fixed black background of paint, removable black sateen covers on glass dishes were substituted for the painted pans and white paper was wrapped around the other half of the dishes to provide a contrasting white background. Light was provided by a 15-watt bulb in a frosted ceiling globe about three feet above the tops of the cages. The tops of the cages were covered with corregated paper to shade the dishes from direct glare.

In experiment No. 2 in the first series (Table I-B-1), over two-thirds of the eggs were laid in the dark containers, but the difference is not significant statistically ($t = 1.38$, whereas 2.23 represents significance at the 5% level). In experiments Nos. 1, 3, and 4, however, a highly significant preponderance of the eggs was laid in the dark containers.

When, however, the shades in the laboratory were drawn and all light was excluded from the test cages (Table I-B-2), the ability of the mosquitoes to select the dark dishes was lost.

These observations then confirm for *A. quadrimaculatus* (1) the preference for oviposition in dim light against a dark background, and (2) the inability of this mosquito to differentiate backgrounds in total darkness—both of which phenomena were first demonstrated for the Albanian anophelines by Bates (1940).

The possible field significance of these findings is not clear, but as Bates has pointed out, total darkness is rare in nature and it is therefore possible that backgrounds of light sand, marl, etc., might influence the oviposition in a particular pool.

III. Preference for certain naturally-varying conditions of ponds.

A. Hard water versus soft water.

These experiments were carred out in an area underlain with limestone. Hence the well waters in the region are very hard. Tests of this hard water against filtered rain water and against distilled water (Table II-A), however, revealed no consistent preference of the females for either hard or soft waters for oviposition. In the first experiment, contrasting well water and rain water, a statistically significant difference ($t = 3.13$) was found, but the three subsequent replicates failed to duplicate the results.

Similarly, when distilled water saturated with calcium sulfate was tested against distilled water alone, or when well-water was made up into 2% or 0.5% calcium chloride solutions and these were

TABLE II.

Effect of certain naturally-varying conditions of ponds on numbers of eggs (means and standard deviations shown) laid by wild *A. quadrimaculatus* in cages.

Materials Tested	Experiment Number 1 Mean	1 S.D.	2 Mean	2 S.D.	3 Mean	3 S.D.	4 Mean	4 S.D.
A. Well water	*12.8	7.1	33.7	26.2	135.7	85.0	252.5	105.7
Rain water	*44.0	21.1	19.2	15.9	103.2	65.3	271.3	163.3
Well water	65.7	41.0	145.3	156.0				
Distilled water	36.3	35.1	118.8	97.3				
Well water	15.8	28.5						
$CaCl_2$ (2.0%)	2.0	4.4						
Well water	88.7	44.3						
$CaCl_2$ (0.5%)	55.2	44.5						
Distilled water	240.3	207.8						
$CaSO_4$	165.0	124.6						
B. Muddy water	102.7	109.3	184.8	312.3	262.5	441.9	35.2	24.6
Well water	140.0	69.7	90.0	62.7	229.5	183.0	142.0	187.6
C. Algae in well water	101.8	70.8	85.2	56.9				
Well water	58.0	10.9	57.8	44.6				
Spirogyra in pond water	389.8	207.5	95.0	52.0	200.8	169.5	74.7	65.5
Well water	247.0	202.1	215.7	164.3	163.5	116.9	128.0	112.6
D. 2.0% sodium chloride	184.2	74.2						
Well water	311.0	273.1						
Physiological saline	156.8	187.1						
Well water	170.5	115.4						
E. KH_2PO_4 (0.5 mg/1.)	123.5	35.5	21.0	28.5	82.0	64.8	1.0	1.4
Well water	130.2	176.3	16.8	15.6	79.3	49.3	8.8	15.8
F. 0.1% $(NH_4)_2CO_3$	166.3	101.5	360.3	742.9				
Well water	169.7	109.5	444.5	372.7				
0.001% $(NH_4)_2CO_3$	234.8	187.4						
Well water	304.7	153.2						
1.0% $(NH_4)_2SO_4$	103.5	97.9	57.5	54.1	27.2	30.9	28.3	20.1
Well water	190.0	158.0	102.7	93.3	70.4	92.9	53.5	48.5
G. 2.0% tannic acid	154.3	170.4	55.7	45.2	†34.5	16.6	76.3	69.1
Well water	236.2	216.7	59.8	23.9	†169.0	39.3	105.2	25.4
H. pH 3.0	111.0	82.4	109.7	66.2	‡100.3	60.2	91.7	25.1
pH 8.4	138.5	166.3	223.7	215.5	‡205.8	82.6	263.0	218.8
pH 7.1	155.8	101.1	163.8	73.4	36.0	15.9	55.7	22.9
pH 8.1	175.3	41.3	178.0	90.2	75.7	55.7	70.7	45.0
pH 3.1	31.2	15.9	21.2	13.9	195.3	109.9	94.0	8.7
pH 7.1	30.7	15.2	36.2	14.5	251.5	181.2	167.0	78.9

* Statistically significant difference (t=3.13).
† Statistically significant difference (t=7.04).
‡ Statistically significant difference (t=2.31).

tested aganst well water alone, again no preference was exhibited in favor of the media high in calcium ions. (Table II-A).

Bates (1940), on the other hand, found that *A. atroparvus* was definitely attracted to solutions of $CaSO_4$ for oviposition.

These experiments would indicate that hardness of waters or even unnaturally high concentrations of the calcium ion do not significantly influence the females of *Anopheles quadrimaculatus* in their selection of a site for oviposition.

B. *Muddy water versus clear well water.*

In these experiments, a fine loam mud, taken from the bottom of a pond recognized as a prolific breeder of *A. quadrimaculatus,* was placed in half the test dishes. Originally the mud and pond water were mixed together in such proportions that the bottom-sediment after 24-hours of standing made up about half the volume. This mixture was then stirred vigorously and 10 cc. of the mixture were poured into each treated dish.

No consistent tendency for the females to oviposit in either the muddy or the clear water was discernible (Table II-B). Bates (1940), on the other hand, found that "mud and rain water were clearly preferred by the mosquitoes" (*A. atroparvus*).

C. *Pond water and algae versus well water.*

In the first two of these experiments (Table II-C), about 2cc. of a mixture of pond water and an unidentified globular green alga were placed in half of the dishes of well water and tested against untreated well water. In neither experiment were any statistically significant data recorded in evidence of a definite preference by the females for oviposition in the dishes containing this alga. In both experiments, however, the larger number of eggs was laid in the dishes containing algae.

In a second series of experiments, pond water rather heavily inoculated with *Spirogyra* was contrasted with well water. No significant preference was exhibited here either.

D. *Saline versus fresh waters.*

Bates concludes that "sodium chloride is not the factor that induces mosquitoes (or at least atroparvus) to lay eggs in brackish water." Data in Table II-D suggest that for *A. quadrimaculatus* also, salinity exerts no statistically detectable influence on the choice

of the oviposition medium. Kligler and Theodor (1925), on the other hand, conclude that three species of anophelines from Palestine "showed a decided preference for fresh water or water of low salt content".

None of the eggs laid in the 2.0% saline solution darkened normally, and, of several hundred transferred to fresh water the morning after they were laid, only 12 subsequently hatched. The eggs laid in the normal saline solution were distinctly lighter in color than normal eggs but, when they were transferred to fresh water, they hatched apparently normally. In one of the dishes of 2.0% saline, a clump of 125 eggs had sunk to the bottom.

E. Potassium phosphate solutions versus well water.

In these experiments (Table II-E), potassium phosphate solutions containing phosphorus in concentrations of 0.5 mg. per liter were tested against well water. There is no indication whatever that the females preferred one medium over the other.

F. Ammonia-bearing waters versus well water.

In the first group of these experiments, ammonium carbonate was used in concentrations of 0.1 and 0.001%. No preference for the well water was displayed by the ovipositing females even though the 0.1% solution proved toxic to the eggs (Table II-F). Eggs laid in this solution were all lighter in color than those laid in the well water and many of them even turned an orange color. Those set aside in fresh water failed to hatch. Eggs laid in the 0.001% solution hatched apparently normally.

In a second group of experiments, a 1.0% solution of ammonium sulfate was tested against well water. In these experiments also, no statistically significant preference was demonstrated by the ovipositing females. It is true, however, that in all experiments the females laid many more eggs in the dishes containing only well water than in the dishes containing the ammonium sulfate and ammonium carbonate solutions.

G. Tannic acid solutions versus well water.

In these four experiments (Table II-G), a 2.0% solution of tannic acid was contrasted with well water. Eggs laid in the acid solution were mostly orange, though some were a normal black. Most of the eggs burst open.

Except in experiment No. 3, no statistically significant preference for well water was exhibited, although such a preference is suggested by the fact that in each experiment most of the eggs were laid in the well water. In experiment No. 3, for some reason or other, a highly significant number of eggs was laid in the well water ($t = 7.04$).

H. Preference for oviposition medium of high or low pH.

In these experiments (Table II-H), oviposition media characterized as follows were contrasted: low pH (3.0) versus high pH (8.4); medium pH (7.1) versus high pH (8.1); medium pH (7.1) versus low pH (3.1). MacElvaine's buffers (citric acid and disodium phosphate) were used throughout and the reaction was checked with a Hellige Comparator. The solutions were diluted 1:20 with distilled water before testing.

When they were given the choice of an acid or an alkaline medium for oviposition (pH 3.0 vs. pH 8.4), the females in all cases laid more eggs in the alkaline medium, but in only one of the four experiments (number 3) was this choice statistically significant.

Similarly when the choice lay between media of alkaline and nearly neutral reaction (pH 8.1 vs. pH 7.1), the alkaline seemed slightly preferred, but in none of these four experiments was the preference of significant magnitude and dependability.

Also when the acid and nearly neutral media were contrasted (pH 3.1 vs. pH 7.1), the neutral medium seemed to be preferred in three out of four tests, but these preferences also could not be supported statistically.

Thus in eleven out of twelve experiments the greater number of eggs was laid in the less acid of two media presented to the females for oviposition; but in only one was the difference of statistical significance.

IV. Preference for certain artificially induced conditions of the media.

A. Ferric chloride and aluminum chloride solutions versus well water.

The evidently uninhibited oviposition of females in media toxic to their eggs (see experiments above on sodium chloride, ammonium carbonate, ammonium sulfate, and tannic acid) suggested further tests on the limits of toleration—if any exist all—of toxicity

of the oviposition medium. It was decided to test solutions of ferric chloride and aluminum chloride.

In only one of the experiments (number 4 on ferric chloride) was there any statistically significant (5% level) preference shown for the well water, even though both solutions proved very toxic to the eggs. In the fourth experiment with $FeCl_3$ a t value of 3.25 was calculated. In both solutions the eggs failed to darken and many burst open. In all the experiments but one, however, slightly fewer eggs were laid in the poison solutions. (Table III-A).

TABLE III

Effect of certain artificially-induced conditions of the media on numbers of eggs (means and standard deviations shown) laid by wild *A. quadrimaculatus* in cages.

Materials Tested	Experiment Number							
	1		2		3		4	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
A. 1.0% $FeCl_3$	180.3	90.8	219.5	98.2	119.0	73.5	*111.3	23.1
Well water	186.2	64.9	299.2	126.1	116.5	40.3	*175.7	39.4
1.0% $AlCl_3$	61.7	24.3	101.7	26.7	84.8	78.7	93.7	91.1
Well water	64.0	34.9	149.5	55.3	145.5	112.3	143.5	92.3
B. 5.0% sucrose	119.7	124.6	176.5	167.6	143.7	42.5	103.3	125.4
Well water	67.8	100.7	160.0	161.7	126.2	40.0	62.5	62.3

* Difference statistically significant (t=3.25)

B. Five per cent sugar solution versus well water.

Since poisonous solutions were ineffective in inhibiting oviposition, the question arose: Can solutions of adult foods attract females to a particular medium for oviposition? It was decided to try a 5.0% solution of sucrose.

In each of the four experiments, a greater number of eggs was laid in the sweetened water, but in none was the preference statistically significant. (Table III-B).

SUMMARY AND CONCLUSIONS

Wild-caught females of *Anopheles quadrimaculatus* were placed in cages, where they were allowed to oviposit in dishes containing various solutions and suspensions.

It was found that gravid females of *A. quadrimaculatus*, if they were provided with dim light, chose dark, rather than light, containers in which to deposit their eggs.

In none of the other experiments, however, was any convincing statistical evidence accumulated in favor of the existence of any preference for any oviposition medium tried. The factors tested were: hardness of waters, concentration of calcium ions, muddiness, presence of algae, salinity, phosphorus content, ammonia content, tannic acid content, pH, presence of ferric chloride or aluminum chloride, and the presence of sucrose in the medium.

REFERENCES

Bates, Marston. 1940. Oviposition experiments with anopheline mosquitoes. Amer. Jour. Trop. Med., *20:* 569-582.

Kligler, I. J. and O. Theodor. 1925. Effect of salt concentration and reaction on the development of *Anopheles* larvae. Bul. Ent. Res. *16:* 45-49.

REVIEW OF RECENT PUBLICATIONS ON THE PROPHYLAXIS AND TREATMENT OF MALARIA

(A report to the National Malaria Committee)

By Herbert C. Clark, M. D.
Panama, R. de P.

This is submitted as a member's annual report to the Chairman of the Subcommittee on Medical Research of the National Malaria Committee. The period covered is from September, 1940 to September, 1941 and these abstracts cover only the literature available on the Isthmus of Panama. The review does not include research work on new drugs that have not passed the period of animal investigation. It is prepared, chiefly, as a digest for the general profession and includes representative reports from various parts of the world.

The trend of the general reports for this year indicates that where mass treatment of the poor is being done quinine is the drug of choice because of its lower price and the general knowledge of the drug and its safety in the hands of non-medical personnel. Atabrin is the drug selected by most hospitals and private practice. Both of these drugs are very valuable and war conditions may make it necessary to employ many other forms of anti-malarial drugs. It still seems to be the consensus of opinion that some cases of malaria and some malaria carriers cannot have these infections "eradicated" by any form or length of treatment. Interest is growing in the Sulfonamide group of drugs as shown by their use in practice and by those conducting laboratory experimentation.

Since quinine is our oldest form of anti-malarial treatment the abstracts will start with this drug and then list the digests concerning synthetic preparations.

Kerbosch (1) in discussing the business of Cinchona culture points out that the world's *need* for quinine is not the same thing as the world's *demand* for quinine. He does not believe that the prevalent idea regarding the high cost of quinine is an important factor in limiting the consumption. In 1933 the official price of quinine was decreased 25 per cent but this reduction in price was not followed by a material increase in consumption. Governments that purchase quinine for free distribution are generally furnished

with the drug at rates lower than the market price. He points out that the cost of quinine is not a very large item in comparison with the cost of an efficient anti-malaria organization which supervises its distribution.

Banerjea (2) comments on the improved method of manufacture and sale of quinine tablets in the United Provinces of India. He describes the procedure now in force where the annual sales of quinine during the last six years have increased from 500 to 5,000 pounds. The installation of modern power-driven machinery has resulted in a reduction in the cost of the conversion of quinine powder into tablets to about one-third the former cost. These tablets can be purchased in packets containing 5 tablets in about 2,500 post offices, or from rural postmen who visit even the remotest villages. Attempts are being made to enlarge the selling agency.

Craig (3) makes an energetic protest against the adoption of the "short-term" treatment of malaria with quinine. He maintains that there is no adequate evidence that it results in either an efficient premunition or an immunity. It favors transmission through favoring the development of carriers and thus perpetuates infections. He believes that the vast majority of infections can be eliminated by the administration of quinine in adequate doses for a considerable length of time.

McMurdo (4) reports that the malaria records for the 1940 Army maneuvers were very low in comparison to the 1938 and 1939 rates. He attributes this to the use of mosquito bars, Bamber oil repellant and the prophylactic use of quinine in 5-grain doses daily while on maneuvers.

Field (5) records an excellent report on the chemotherapy of malaria in the Federated Malay States for both the treatment and prophylaxis. It comprises 180 pages of very interesting records. His summary states that among those drugs studied, *quinine* still ranks first in current practice, by reason of its clinical effectiveness and almost complete absence of toxicity, coupled with the widespread knowledge of its use and dosage. In certain circumstances, the synthetic drugs (atebrin and plasmoquine) represent a notable scientific advance and they possess a very special value.

De (6) reports on his technique for the treatment of algid cases of malaria in his tea-garden practice. When a case has been diagnosed as one of the choleraic type of malaria he starts a saline infusion either by direct vein puncture or by opening the vein. He then takes a syringe with the desired amount of quinine dissolved

in one or two cubic centimeters of distilled water and, while the saline flows on, injects the quinine into the saline solution through the rubber tube that connects the saline funnel and the needle. The rubber tube is taken as the vein, sterilized with spirit and punctured. The quinine solution is given very slowly, so that it is well diluted with saline and this eliminates shock. He claims the following advantages:

(1) Most of the cases come so late that saline infusion has to be undertaken at once, before anything can be done in the way of laboratory diagnosis. In such cases, he generally takes a blood film first and begins the saline injection, and by the time it is prepared and the administration has begun, the blood film has been examined. If it is positive the quinine is given by the above method. Hence, further puncture or opening a vein is avoided.

(2) The exact amount of quinine can be given as desired or necessary. If the quinine is mixed up with saline, there is the chance of a loss of a certain percentage of the quinine, as the whole quantity of saline taken for infusion may not be required, and also some cases react badly after a few ounces of saline.

(3) The most important advantage is that quinine can be stopped at the slightest possible sign of quinine shock and any intravenous circulatory and respiratory stimulant can at once be given by this method. His procedure in bad cases of choleraic malaria is that he first gives 0.5 to 1 cc. of adrenaline chloride by this method, and then gives the quinine. This prevents any possible occurrence of shock from quinine.

Wijerama (7) treated ninety-five febrile malaria patients with totaquina and 132 cases with quinine bisulphate. In one series each case received 15 grains a day of totaquina or quinine bisulphate for five days. In a second series each drug was given in a dosage of 20 grains a day for five days. All three types of malaria cases were included in the experiment. The author concluded that totaquina was more effective than quinine bisulphate.

Note—Totaquina is now prepared in tablets of 0.25 gms. in Bogota, Colombia, by the Instituto Nacional de Higiene, Samper-Martinez.

Junge (8) observed 20 Europeans in Liberia who had taken atebrin as a prophylactic over a period of 7 years. Altogether each adult took 143 gm. during the period and no injury to health which could be attributed to atebrin was observed. The condition of the blood remained normal and pregnancy and parturition were not af-

fected. Yellow coloration of the skin, however, was constant. One individual who had taken prophylactic atebrin by mouth for six years had an attack of malaria during the period and it could only be controlled by the injections of atebrin. The prophylactic dose at first given was 0.1 gm. daily. No malaria was seen during 3½ years under this dosage. For 1½ years the dose was then reduced to 0.03 gm. given on one day each week, but this was not satisfactory since four-fifths of the people suffered attacks of malaria. The best dosage appears to be the daily use of 0.05 gm.

Cannistraci (9) treated 192 cases of malaria in Messina with atebrin, 0.3 gm. a day for 6 days, followed, after an interval of 2 days, by plasmoquine, 0.03 gm. a day for 4 days. A second course of treatment was given two months later. There were no instances of drug intolerance and no relapses.

The drugs were also used as prophylactics. Among 242 people so treated there were only 3 cases of malaria as compared with 126 cases among 854 people receiving quinine prophylactically. As a prophylatic, atebrin 0.3 gm. on one or two days a week, is recommended. Children can also support this dose.

Lamprell (10) reports the use of quinine and atebrin in some tea estates of Assam where malaria is hyperendemic. The amount of funds available for mosquito control were not sufficient to effect much improvement. In 1938 antilarval measures were suspended and the funds were used for prophylatic drug measures. One group received a five-day course of atebrin and thereafter each adult was given 0.2 gm. of atebrin one day a week from the end of May till mid-September. Members of the second group received quinine on five consecutive days every third week.

A third group acted as a control. There was a diminished prevalence of the disease in both treated groups during the drug administration but the rate was higher soon after cessation of treatment than in the control group. This was especially true of the atebrin group.

The diagnosis were all clinical since no blood examinations were made.

Field et al (11) report the use of plasmoquine in the plantations of the Federated Malay States. Their summary follows:

(a) Plasmoquine was given regularly (twice a week) to 96 percent of the population averaging 643 people. The dose was 0.02 gm.

(b) There was little evidence of transmissions of *falciparum*

infections during the administration. Crescents were found only on six occasions. One infant out of 40 born on the plantations during this period of treatment contracted *falciparum* malaria.

(c) Observations on this form of malaria appeared to indicate that the prophylactic plasmoquine did not prevent the development of infection in at least a portion of persons who had, we believe, received fresh infective bites. Once *falciparum* infection had been acquired the plasmoquine did not materially influence either the general course or the severity of attacks.

(d) It is concluded that in areas where fresh transmission of *falciparum* malaria is slight and infections are mostly residual or contracted elsewhere, the prophylatic use of plasmoquine in a dosage of 0.02 gramme twice a week may not markedly affect either the clinical course or the incidence and severity of clinical attacks.

Field (12) and his co-workers also report on its use in *P. vivax* malaria. They conclude that gametocidal prophylaxis based on the use of 0.02 gm. of plasmoquine twice a week may not significantly lower the incidence or prevent the transmission of this species in heavilv infected populations exposed to intense anophelism even though these populations are relatively isolated from outside sources of infection of man and mosquito.

Dikshit's (13) experiments indicate that neither plasmoquine nor atebrin, in doses equivalent to human therapeutic doses, influences the activity of non-pregnant uterine muscle. Plasmoquine given in toxic doses to the mother does not filter through the placenta in sufficient quantity to influence the respiration or heart action of the foetus.

Bispham (14) reviews the records of toxic reactions that occurred following the use of atabrine and concludes that toxic reactions are so few and so slight that this feature is of small importance and though it should always be considered it should not deter physicians from its use.

Wilkinson (15) describes three cases in which mental derangement followed the use of atebrin in the treatment of malaria. One of them had a history of previous mental instability. All three made rapid recoveries. None had pigmentation of the skin or gastro-intestinal disturbance.

A translation of Raskine's (16) report on the use of acriquine and quinoline 31 has been summarized as follows:

1. The treatment of malaria by the combined use of acriquine and quinoline 31 is effective.

2. Administration by mouth, for 5 successive days, of 0.1 gm. acriquine three times a day and 0.03 quinoline twice a day cut short the fever of subtertian malaria in 3.0 days, and of benign tertian in 3.1 days.

3. In subtertian malaria the schizonts disappear in 4.3 days, in benign tertian in 4 days.

4. In subtertian the gametocytes disappear by the sixth day.

5. Slight abdominal pain lasting 2 to 3 days was present in 16 cases. In all these cases the same preparations were given when treatment was repeated.

Chopra et al (17) report on Haffkinine in India. It appears to behave exactly as does atebrin. Haffkinine is now known as acriquine.

Chopra et al (18) report on crinodora, at first called palusan. It is apparently atebrin prepared in Italy. It acts in the same manner.

Ballero (19) reports on Italchina, a new acridine derivative. It causes no pigmentation of the skin. The results of its use in 152 cases of malaria were good. The dose given was 0.30 gm. a day for 7 days. The author claims it is better than quinine or other synthetic preparations. Febrile relapses, however, were recorded in 16.6 per cent of the cases.

Chopra et al (20) treated 12 cases of malaria with M. & B. 693, seven tertian, four malignant tertian and one quartan. Doses of 4 gm. daily, in tablet form, for five days controlled the symptoms of the disease. It caused the disappearance of all forms of the tertian parasite, of the asexual forms of *P. falciparum*. When the drug was given in smaller doses (1.5 gm.) parasites reappeared within two weeks. Parasites in the quartan case were still present after the course of treatment.

Chopra & Basu (21) used M^3 which is composed of mercuric manganese iodide and concentrated extract of spleen on eight volunteers on alternate days over a period of a month. The initial dose was one pill. This dose was regularly increased, the final two doses each consisting of 8 pills. Infected mosquitoes (*P. falciparum*) were fed on these volunteers varying in time from the beginning of treatment to a period two months after treatment. In all cases infection took place after normal periods of incubations.

Yamamoto (22) treated 14 cases of malaria with sulfanilamide. He concluded that the drug was not an efficient antimalarial drug.

Pakenham and Rennie (23) report the effect of sulphathiazole (M & B. 760) on a general paralytic who was inoculated with

P. vivax. The maximum dose used was 2 gm. three times a day. After the first day's treatment the parasite count fell from 90 to 4 per hundred fields, and remained at a low level for nine days when quinine was given.

Winckel (24) reports the use of neoarsphenamine in Amsterdam to control the fever of therapeutic malaria in the treatment of dementia paralytica. He concludes that the intravenous injection of this drug constitutes a means of either changing a double tertian fever into a single one or, at least, allowing the patient a few afebrile days. In quartan malaria he could not gain this result. It is his opinion that neoarsphenamine cannot replace quinine in the treatment of malaria. For definitely cutting short the fever course, after inoculation by the injection of blood, 5 gm. of quinine sulphate in five days is required and is sufficient; clinical relapses were not encountered.

Cole et al (25) have used Thio-bismol (sodium bismuth thioglycollate) in arresting therapeutic malaria in cases that reach a critical condition as a result of malarial fever. The average 0.20 gm. intramuscular dose contains 75 mgm. of metallic bismuth. They report a series of 103 cases and state that in a prolonged remittent fever a single injection of thio-bismol generally procures a forty-eight hour respite from fever. Repeated injections can arrest clinical therapeutic malaria for long periods. They do not recommend the drug as a substitute for quinine in terminating malaria but by its use they feel that many untoward therapeutic malaria results have been avoided.

Garra (26) reports the results of treatment of 29 cases of malaria by intravenous injections of antimony tartrate according to the method devised by De Nunno (See Trop. Dis. Bull. 1939. Vol. 36. p. 500). He treated 12 Italians and 17 natives in Italian East Africa. There were 8 *P. vivax* and 13 *P. falciparum* infections and in 8 of the patients no parasites could be found. He administered a 1 per cent solution of antimony tartrate in distilled water on alternate days beginning with a dose of 6 to 10 cc. and increasing the amount 2 cc. until a maximum of 14 cc. was given. The total amount given a patient varied from 120 to 200 cc. He favored the use of this treatment particularly in those cases refractory to other antimalarial drugs.

Pizzillo (27) reports the treatment of 57 patients whose primary attacks of malaria, from 7 to 20 months previously, had been treated with intravenous injections of adrenalin. Thirty-eight of

this series had had *P. falciparum* infections. He claims complete disappearance of parasites and no relapses and in none could be found any splenic enlargement.

Most (28) in his summary on malaria in drug addicts claims that New York is an endemic area for the occurrence of malignant tertian malaria (*P. falciparum*). The disease occurs almost exclusively among heroin drug addicts who practice the common use of hypodermic syringes. Infection is direct from man to man.

Black (29) reports an unduly high proportion of malaria infections among patients attending a syphilis clinic in the out-patient department of a hospital in Rutherford County, Tennessee. Investigation showed that it was an accidental transmission of malaria through intravenous injections of neoarsphenamine.

Wenyon in 1926 (Protozoology, p. 955) reported an almost exactly similar occurence in which one man who was positive for parasites infected ten succeeding men, and produced in them attacks of malignant tertian malaria, which were fatal in some of the cases. The treatments that were given in this series of men were injections of salvarsan. The experiments do not speak very well for the efficiency of neoarsphenamine and salvarsan as antimalarial drugs and yet one, even now, frequently hears of these drugs being used for such a purpose.

Chung et al (30) report cases of malaria among heroin addicts. They describe the intravenous method of giving the drug in three heroin dens, a method devoid of proper precaution. Confirmation of the assumption that infection of malaria, and of other diseases that might be transmitted through the common use of hypodermic syringes and needles, was afforded by finding crescents and ring forms of *P. falciparum* and gametocytes of *P. vivax* in the residual fluid in syringes used in two of the three dens investigated.

Clark and Komp (31) reported on ten years of drug control in certain Chagres River villages in the Republic of Panama. The results were good in so far as clinical control and labor efficiency were concerned but about 25 per cent of the cases developed a relapse or re-appearance of the parasites regardless of whether they received quinine-plasmoquine or atebrin-plasmoquine. No evil results were noted in the atebrin group. Quinine gave just as good results as atebrin although the people prefer to take atebrin. In the *eleventh* year's observation 40 babies in these villages failed to show a malarial infection before they reached the age of 12 months. This would indicate low transmission. The average monthly parasite rate in

the quinine-plasmochin group was 8.2 per cent, in the atebrin-plasmochin group 10.1 per cent, while the control group was 29.3 per cent. The cumulative rates for the year were respectively 18.7 per cent, 23.9 per cent and 42.7 per cent.

A brief summary of "Malaria in War" is offered by Christophers et al (32): "Malaria may modify or even determine the results of a military campaign as history has several times shown. Another aspect of war malaria is the liability for malaria to be transmitted in theaters remote from the war due to the introduction in large numbers of infected returning soldiers."

"Are we satisfied with quinine prophylaxis and if so have we an ample supply of this drug or of the new synthetic drugs?"

Wenyon: I am definitely of the opinion that prophylactic quinine does prevent actual attacks of malaria, though it does not prevent infection.

Manifold: I am perfectly certain that had I not taken 10 grains of quinine a day in the Kilwa area in East Africa that I should have died. Actually during the 18 months I was taking this dose, I had my 10 to 14 days regular attacks of malaria, but they were mild and after the attack one could get up and carry on. Similarly, I am certain that my chances of an attack of blackwater fever were greatly reduced by prophylactic quinine. I think that for selected troops whom it is desired to keep on their feet for a period of a few weeks prophylaxis by drugs is useful, but it is not desirable to employ it for an entire force irrespective of circumstances. We also realize that once quinine is withdrawn the malaria rate will rapidly increase even after the troops have left the malarious area. It has been the custom recently to use 0.2 grammes of atebrin twice weekly in lieu of quinine. The subject of culicifuges (repellents) has been mentioned. We have an antimosquito cream based on the Dover's cream that has been recommended to me by Colonel Covell. The formula we use is:

Oil of Citronella, 18.25 per cent.
Camphor, 1.00 per cent.
Cedarwood oil, 9.00 per cent.
Paraffin, duram, 26.75 per cent.
Paraffin, molle, white, 45.00 per cent.

It is supplied to the troops in 1 oz. aluminum screw top containers. Applied to hands, face, neck and ears it will keep off mosquitoes for six hours, and it is an excellent protection against sandflies. It is now in use in India, Egypt and Palestine.

Another antimalaria measure of use is the spraying of huts, barrack rooms and tents with pyrethrum extracts of various formulae. A popular one is:

Paraffin, 2nd grade, 124 oz.
Liq. ext. of pyrethrum, 2 oz.
Carbon tetrachloride, 4 oz.
Oil of citronella, 8 oz.
Petrol, 22 oz.

We feel that ample supplies are available of antimalarial drugs as well as for their manufacture. It will require time to train sufficient malaria personnel.

Col. S. P. James: My inclination is to concentrate effort on *direct measures applicable to the individual soldier and to the barracks, hut or tent in which he lives,* rather than to concentrate effort on indirect measures in the general environment. Spraying of quarters, well disciplined use of mosquito nets and quinine prophylaxis.

Hutton et al (33) report that a large number of seamen and passengers arrive in London with severe infections of subtertian malaria acquired in tropical ports of call. A laboratory diagnosis can be not made on board and therefore malaria should be suspected in every case of sudden illness arising 10 days or more after visiting tropical ports. Quinine or atebrin should be given to every suspicious case. The author recommends a prophylactic course of atebrin, 0.3 gm. a day for 7 days, during the voyage home. A product identical with atebrin, mepacrine hydrochloride, is now being made in England.

The Atlantic conference (34) in May, 1940 initiated by the Surgeon General of the United States Public Health Service, concluded that one of the most pressing problems in malaria lies in the field of chemotherapy. Available antimalarial drugs are only effective against trophozoites. The chemotherapeutic approach should not be directed solely towards the discovery of drugs with an action similar to that of quinine or atabrine, which are effective only against trophozoites, but also toward a drug that will reach the parasite in its reservoir outside of the red blood cell and thus serve as a true causal phophylactic. . . . As an example showing that the prospects of success in such a search are not too unfavorable, the fact may be cited that sulfanilamide, which does not remotely resemble quinine or the other antimalarials, seems to be effective in monkey malaria.

Thus one can see the trend toward research in chemotherapy.

The hope to provide a treatment capable of sterilizing the parasite carrier, thereby preventing relapse and transmission.

REFERENCES

1. Kerbosch (M.) Some notes on Cinchona Culture and the World Consumption of Quinine. Bull. Colonial Inst. Amsterdam. 1939. Dec. Vol. 3 No. 1. pp. 36-51.

2. Banerjea (A. C.): Note on the Manufacture and Retail Sale of Quinine Tablets in the Rural Areas of the United Provinces. Jl. Malaria Inst. of India. 1939. Dec. Vol. 2. No. 4. pp. 377-386.

3. Craig (Charles F.): The "Short-Term" Treatment of Malarial Infections with Quinine. Amer. Jl. Trop. Med. 1940. March. Vol. 20. No. 2. pp. 239-248.

4. McMurdo, (H. B.): Malaria 1940 Maneuvers, Luzon, Philippine Islands. Milit. Surveon. 1940. Sept. Vol. 87. No. 3. pp. 252-255.

5. Field (J. W.): Notes on the Chemotherapy of Malaria. Bull. Institute for Med. Res. Federated Malay States. No. 2 of 1938.

6. De, (R. K.): A Simple Technique of Giving Intravenous Quinine with Saline. Jour. Trop. Med. & Hyg. Vol. 43. No. 13. pp. 186-187. July 1, 1940.

7. Wijerama (E. M.) Totaquina in the Treatment of Malaria. Jl. Ceylon Branch Brit. Med. Assoc. 1939. Nov. Vol. 36. No. 6. pp. 403-406.

8. Junge (Werner): The Tolerance and Dosage of Atebrin as a Prophylactic. Arch. f. Schiffs-u. Trop-Hyg. 1939. Sept. Vol. 43. No. 9. pp. 409-411.

9. Cannistraci (Salvatore Carlo): Cure and Prophylaxis of Malaria with Synthetic Products. Riv. di Malariologia. Sex. 1. 1940. Vol. 19. No. 2. pp. 118-120.

10. Lamprell (B. A.): Quinine and Atebrin in the Control of Malaria with Special Emphasis on the Practical and Economic Viewpoints. Indian Med. Gaz. 1940. May. Vol. 75. No. 5. pp. 266-274.

11. Field (J. W.) Niven (JJ. C.) and Mitchell (J. F.): Field Observations on the Effect of Prophylactic Plasmoquine on the Incidence, course and Severity of *Falciparum* malaria. Bull. Institute Med. Res. Federated Malay States. No. 4 of 1940.

12. Field (J. W.), Niven (J. C.), Hodgkin (E. P. and Mitchell (J. F.): Field Observations on the Effects of Prophylactic Plasmoquine on the Incidence, Course, Severity and Transmission of P. *vivax* malaria. Bull. Institute Med. Res. Federated Mayla States. No. 3 of 1940.

13. Dikshit (B. B.): Plasmoquine in Pregnancy with Special Reference to the Action on the Foetus. Jl. Malaria Inst. of India. 1939. Dec. Vol. 2. No. 4. pp. 387-393.

14. Bispham, W. N., Toxic Reactions Following the use of Atabrine in Malaria. Amer. Jour. Trop. Med. Vol. 21, No. 3, 1941. pp. 455-459.

15. Wilkinson (P. B.): Mental Disturbance after the Exhibition of Atebrin. Caduceus. Hong Kong. 1939. Nov. 18. No. 4. pp. 267-271.

16. Raskine (A. Ja.): The Treatment of Malaria with Acriquine and Quinoline 31. Med. Parasit. and Parasitic Dis. Moscow. 1839. Vol. 8. No. 6.

17. Chopra (R. N.), Hayter (R. T. M.) and Sen (B): Haffkinine (Acriquine), an Atebrin-like Compound prepared in India. In Indian Strains of Malaria. Indian Med. Gaz. 1940. Apr. Vol. 75. No. 4. pp. 200-201.

18. Chopra (R. N.), Hayter (R. T. M.), Sen (B.) and Talukdor (M.): Crin-

odora (Palusan) in Indian Strains of Malaria. Indian Med. Gaz. 1940. Apr. Vol. 75. No. 4. pp. 202-204.

19. Ballero (Stefano): Treatment of Malaria wtih a new Product, "Italchina." Riv. di Malariologia. Sez. 1. 1940, Vol. 19. No. 2. pp. 111-117.

20. Chopra (R. N.), Hayter (R. T. M.), and Sen (B.): M & B. 693 in Indian Strains of Malaria. Indian Med. Gaz. 1939. Nov. Vol. 74. No. 11. pp. 658-660.

21. Chopra (R. N.) and Basu (B. C.): Failure of "M_3" in Prophylaxis of Indian Strains of Malaria. Jl. Malaria Inst. of India. 1939. Sept. Vol. 2. No. 3. pp. 253-255.

22. Yamamoto (Kinzaburo): Sulfanilamide In Malaria. Japanese Jl. Dermat. & Urol. 1939. Oct. 20. Vol. 46. No. 4. pp. 78-79.

23. Pakenham-Walsh (R.) and Rennie (A. T.): Sulphathiazole in Malaria. Lancet. 1940. Oct. 19. p. 485.

24. Winckel, (C. W .F.): Neoarsphenamine to Manage Course of Fever in Therapeutic Malaria. Jour. A. M. A., Vol. 116, No. 24. pp. 2660-2663, June 14, 1941.

25. Cole (Harold N.). De Oreo (Gerard A.), Driver (James R.), Johnson (Herbert H.) and Schwartz (Walter F.): Use of Bismuth Injections to Manage Course of Therapeutic Malaria. Jl. Amer. Med. Asso. 1940. Aug. 10. Vol. 115, No. 6. pp. 422-426.

26. Garra (Guiseppe): Treatment of Malaria with Antimony Tartrate according to de Nunno's Method. Riforma Med. 1940. March 30. Vol. 56. No. 13. pp. 410-413.

27. Pizzillo (Guiseppe): Late Results of Primary Malaria Infections treated with Intravenous Adrenalin Injections. Riv. di Malariologia. Sez. 1. 1939. Vol. 18. No. 6. pp. 361-373. German Summary.

28. Most, Harry: Malignant Malaria Among Drug Addicts. Epidemiological, Clinical and Laboratory Studies. Trans. Roy. Soc. Trop. Med. and Hygiene. Vol. XXXIV, No. 2. Aug. 1940 pp. 139-172.

23. Pakenham-Walsh (R.) and Rennie (A. T.): Sulphathiazole in Malaria. Lan-Injections of Neoarsphenamine. Amer. Jour. Hyg. 1940. March. Vol. 31 No. 2. Sect. C. pp. 37-42.

30. Chung (Huei-lan). Lin (W. T.) Wang (C. W.) and Chu (Irving): Transmission of Malaria Among Drug Addicts in Peiping. Demonstration of Malarial Parasites in Syringes used for Intravenous Injections of Heroin. Chines Med. Jl. 1940. Jan. Vol. 57. No. 1. pp. 32-38.

31. Clark (H. C.) and Komp (W. H. W.): Summary of 10 years Observation on Malaria in Panama With Reference to Control with Quinine, Atebrin and Plasmochin Without Antimosquito Measures.

Human Malaria. Publication No. 15 Amer. Assoc. Advanc. Science. Smithsonian Institution Building, Washington, D. C., 1941. pp. 273-284.

32. Christophers, S. R.: Malaria in War. Trans. Roy. Soc. Trop. Med. & Hyg. Vol. XXXIII. No. 3. November, 1939. pp. 277-304.

33. Hutton (E. L.); Napier (L. Everard); Manson-Bahr (Philip): Malaria on Board Ship. Lancet. 1940, Nov. 9 & 30. pp. 603; 696.

34. Surgeon General of the United States Public Health Service: A brief Review of Needed Research in Malaria. Public Health Reports, Vol. 55. No. 40. pp. 1801-1809. October 4, 1940.

MALARIA MORTALITY IN THE SOUTHERN UNITED STATES FOR THE YEAR 1940, WITH SUPPLEMENTARY DATA ON MALARIA IN OTHER STATES*

ERNEST CARROLL FAUST, PH. D.
AND
LOIS DE BAKEY, B. A.

Department of Tropical Medicine
The Tulane Universtiy of Louisiana School of Medicine
New Orleans, La.

INTRODUCTION

At a time when cases of clinical malaria in the Charity Hospital at New Orleans have become so rare that a single case of *vivax* infection is exhibited to students of both medical schools utilizing the hospital, it might seem presumptuous to consider malaria deaths of public interest. It is true that the reported malaria deaths for 1940 were the lowest on record, totaling 1346 for the entire South, or a rate of 3.02 per 100,000 population (based on the 1940 census figures). Nevertheless, such a period of low mortality is ideal for analyzing the situation, in order to discover the chronic foci of the disease.

PRESENTATION AND ANALYSIS OF DATA

The basic data for malaria mortality in the United States are presented in map form (Fig. 1). It is observed that, aside from a few small foci in New York, the Central States, New Mexico and California, malaria deaths for the year 1940 were reported onlv from the Southern States. While the distribution of malaria deaths by counties was extensive throughout the South, there were relatively few local political subdivisions in which a rate of 25 or above was reported. These included the following: Alabama, 6 (Autauga, 42.9; Bullock, 45.4; Crenshaw, 33.8: Dallas, 34.4; Lowndes, 44.1,

---

*Read before the National Malaria Committee, meeting conjointly with the Southern Medical Association, Thirty-Fifth Annual Meeting, St. Louis, Missouri, ber 12, 1941.

and Wilcox, 26.6); Arkansas, 2 (Cross, 26.9 and Desha, 25.8); Florida, 5 (Dixie, 71.2; Franklin, 33.4; Gulf, 28.8; Hamilton, 40.9 and Madison, 24.7); Georgia, 5 (Clay, 28.3; Lee, 25.5; McIntosh, 37.8; Pulaski, 30.5 and Terrell, 30.0); Mississippi, 3 (Choctaw, 29.5; Quitman, 25.7 and Sharkey, 25.9); South Carolina, 5 (Beaufort, 31.8; Berkeley, 29.5; Colleton, 26.6; Dorchester, 25.1; Hampton, 28.6) and Texas, 2 (Frio, 43.4 and Polk, 24.2).

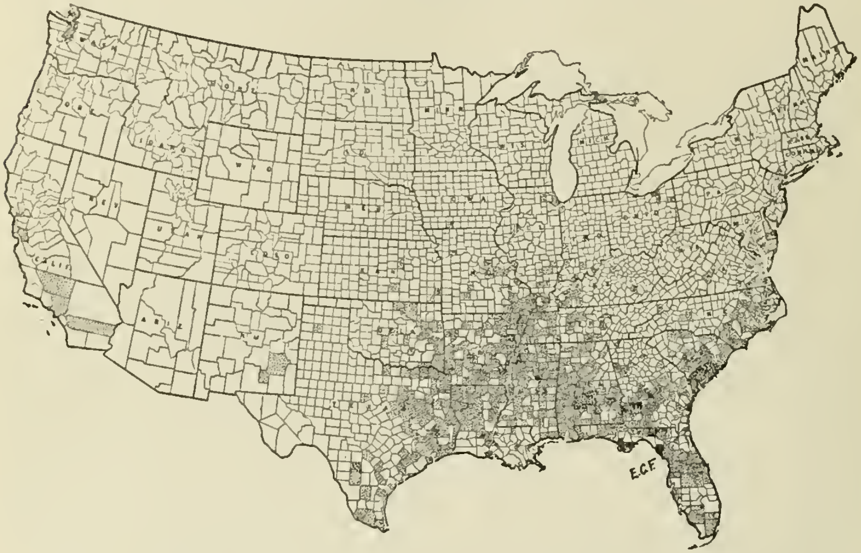


Fig. 1. Map of the United States, showing the 1940 malaria mortality by counties. County areas lightly stippled had a rate less than 25 per 100,000 population; those heavily stippled, a rate between 25 and 49.9; the one county in Florida heavily shaded, a rate in excess of 50. Rates were calculated on the 1940 county populations as reported by the Bureau of the Census.

Of the six Alabama counties referred to above, the rate for Lowndes county represented a decline, that for each of the other counties an increase. In the case of Autauga, Bullock and Crenshaw counties the rate was the highest within the past decade. In Arkansas the two counties with rates above 25 (Cross and Desha) had significantly reduced rates over previous years. Likewise, all of the county foci in Florida and Georgia with moderately high rates showed reductions over previous years. Although in 1940 the malaria death rates for all parishes in Louisiana were less than 25, St. Landry parish had a tripling of deaths from 1938 and a doubling from 1939. In Mississippi, Holmes and Warren counties, with rates under 25, showed significant increases, while Choctaw, Quit-

man and Sharkey counties had slight increases. The lowlands of southeastern Missouri have in recent years indicated a marked reduction in malaria deaths, with a low for 1940 which is possibly an all-time record. Similarly, southeastern Oklahoma has shown marked improvement. Although the record looks bad for the five counties in southeastern South Carolina, each with a rate in excess of 25, four of these actually have reduced rates over previous years. In Tennessee, Madison county had an appreciable increase with its highest rate since 1937. On the other hand, Shelby county had its lowest recorded malaria death rate. In Texas, Bowie and Cherokee counties in addition to Frio and Polk counties referred to above, all had significant increases in 1940 over previous years.

The individual state rates and the average rate for the Southern States for malaria mortality year by year since 1929 are provided in the accompanying chart (Fig. 2). The remarkable drop in the rate since the peak of 1933-1936 is as conspicuous as the sudden rise to this peak. Evidence now seems to indicate that the cyclic rise which might have been expected between 1938 and 1941 has apparently failed to develop, although the curve for Alabama, Kentucky, Louisiana, Oklahoma and Tennessee actually revealed a slight rise for 1938 out of line with the otherwise consistently downward trend.

In previous yearly assays of the status of malaria in the South, one of us (E. C. Faust) has analyzed the data in various ways in an attempt to discover trends which were not otherwise obvious. This year the records have been utilized to provide comparative information based on the number and percentage of counties in the Southern States with one or more reported malaria deaths. Comparison has been made between the lowest year immediately preceding the 1933-1936 peak year for the particular state and the years 1938, 1939, and 1940. In several states the 1938 or 1939 county percentages were in excess of the previous low (i. e., Alabama, Louisiana, Missippi, North Carolina, and Tennessee). These facts indirectly support the view that the 1938 data represent a subdued cyclic peak. However, for 1940, with the exception of Virginia, there was a decrease in the territory in which malaria deaths were reported. This tendency was particularly marked in Florida, Georgia, Kentucky, Louisiana, Oklahoma, Tennessee and Texas, but was so slight in Alabama and Mississippi that it was not statistically significant (See Table 1).

Table 1. Number and Percentage of Counties in the Southern States with one or More Malaria Deaths.

State	Total No. Counties	Previous Low (1930-1933) No.		%	1938 No.	1938 %	1939 No.	1939 %	1940 No.	1940 %
Alabama	67	49	(1932)	73.1	53	79.1	51	76.1	48	71.6
Arkansas	75	63	(1932)	84.0	61	81.3	54	72.0	51	68.0
Florida	67	54	(1932)	80.6	49	73.1	44	65.6	37	55.2
Georgia	159	89	(1931)	56.0	73	45.9	54	34.0	55	34.6
Kentucky	120	26	(1932)	21.7	23	19.2	15	12.5	14	11.7
Louisiana	64	46	(1931)	72.5	51	79.7	40	62.5	33	51.6
Mississippi	84	62	(1932)	73.8	63	75.0	63	75.0	60	71.4
Missouri	114	37	(1930)	32.5	24	21.1	22	19.4	18	15.8
N. Carolina	100	30	(1933)	30.0	36	36.0	31	31.0	26	26.0
Oklahoma	77	32	(1931)	41.5	32	41.5	32	41.5	23	30.0
S. Carolina	46	33	(1932)	71.7	32	69.6	31	67.4	29	63.0
Tennessee	95	30	(1932)	31.5	31	32.6	31	32.6	23	24.2
Texas	243	81	(1930)	32.0	73	28.8	67	26.5	65	25.7
Virginia	100	4	(1932)	4.0	2	2.0	5	5.0	5	5.0
Total	1421	636		44.82	603	42.49	540	38.05	487	34.31

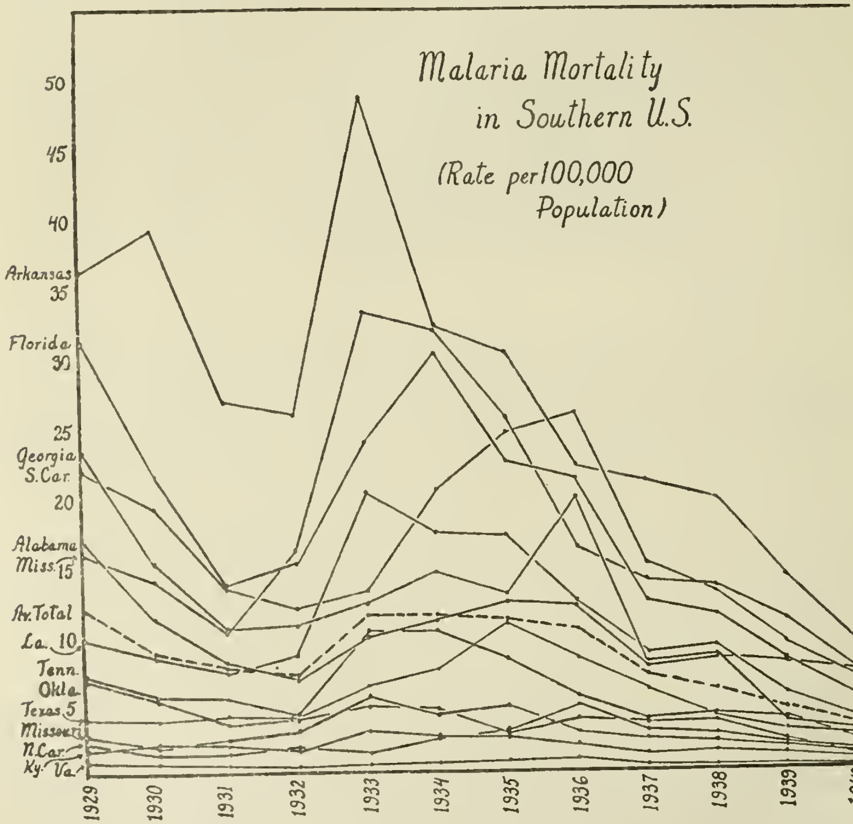


Fig. 2. Graph showing the malaria mortality rates for fourteen Southern States (1929-1940). The broken line represents the average rate for all of these states.

In spite of these two general trends in reduction, i. e., in the malaria mortality rate by counties and in the geographical distribution of malaria deaths in the South, many counties (34 per cent of all in the South) contributed one or more malaria deaths each in 1940. Moreover, these counties constitute an almost contiguous stretch of territory, so that if one were traveling by motor car on principal U. S. highways from Norfolk, Va., to Savannah, Ga.; thence via Macon, Ga., Montgomery, Ala., Jackson, Miss., and Monroe, La., to Shreveport, La.; thence via Houston, Alice and McAllen, to Brownsville, Tex.—65 out of approximately 82 counties traversed (i. e., 10 out of 14 in North Carolina, all 10 in South Carolina, 8 out of 13 in Georgia, 8 out of 9 in Alabama, 5 out of 6 in Mississippi, 7 out of 8 in Louisiana and 17 out of 22 in Texas) would necessarily be counties in which malaria deaths occurred during 1940.

Outside of the Southern States only 57 malaria deaths were reported from the United States for the year 1940. Several of these from New York City were in drug addicts, while deaths occurring in certain localities outside the South were probably the result of exposure to infection in the South or in Tropical America. Thus, even with the low malaria death record for 1940, the South with one-third of the population of the United States had 96 per cent of all the reported malaria deaths.

DISCUSSION

The most striking feature of the 1940 malaria mortality data in the United States and particularly in the Southern States is its indication of reduced death toll. If mortality is a valid index of the amount of malaria in the country, it may reasonably be concluded that the disease has now been confined both in intensity and extent within narrower limits than previously recorded since malaria became a menace to life and health in the South over a century ago. If one may conclude that a 1938-1940 peak was passed without any significant interruption in the consistent decline in the mortality rate, control of the disease may possibly be in sight. What factors have contributed to this reduction?

No definite answer can be furnished to the question just raised, but there may be several contributing causes. The rapidly developing increase in the malaria death rate of 1933-1936 occurred at a time when the South was feeling the full effects of economic depression, when the poorer classes in the population were suf-

fering from malnutrition and were too indigent to procure adequate food and antimalarial drugs or to repair screening, and when naturalistic methods of control were at a low ebb. On the other hand, in the three succeeding years, more plentiful and more nourishing diets were provided, more funds were available for the purchase of antimalarial drugs and for better screening, and naturalistic and anti-larval measures were carried out by state departments of health, supplemented by Federal Aid, to a degree and on a scale previously unattempted. Furthermore, in addition to quinine, atabrine and plasmochin have been utilized extensively in the treatment of malaria. Thus, any one or a combination of several factors may have contributed to the greatly reduced malaria death rate.

It must be remembered, however, that malaria as a primary cause of death is due mostly, if not exclusively to *Plasmodium falciparum*. Hence, the figures on malaria mortality reflect directly only the improved status of *falciparum* malaria. Nevertheless, the reduced extent of malaria not only in the South but elsewhere in the United States suggests that the trend is general and probably includes *vivax* malaria as well.

While the situation is satisfactory, it must not beget complacency. Relaxation of measures carried out intensively in recent years may allow recrudescences to occur within the endemic foci and malaria may spread again to contiguous territory. Possibly with continued treatment of malaria patients in endemic foci the gametocyte rate may become so low that mosquito infection will be difficult, leading temporarily to a condition of anophelism without malaria. Yet as long as susceptible mosquitoes are allowed to breed in our midst, there will be the constant danger of mosquito infection from carriers who have acquired the disease in Tropical America. These heterologous strains from the Tropics will constitute an unusually grave danger, since the population in our territory has no immunity to these strains, which are at times much more virulent than endemic strains. This latter danger is the more real in view of the manning of our tropical defense bases, from which malaria cases are already being sent to base hospitals in our midst for observation and treatment.

SUMMARY

1. Malaria mortality data for the United States for the year 1940 have been presented by states and by counties, with especial consideration to malaria in the Southern States.

2. Analysis of the data shows a continued reduction of the rate, especially since 1938, to an apparently all-time average low rate of 3.02 for the fourteen endemic malaria states in the South. With a population of one-third of the entire nation, the South had 96 per cent of the reported malaria deaths in 1940. These deaths occurred in 34 per cent of the counties in fourteen Southern States.

3. There has been a favorable reduction in the number of counties in the South contributing the malaria deaths.

4. There was an apparent suppression of the 5-7 year cyclic increase in malaria deaths, which should have occurred in 1938-1940 in the South. Yet in 1938 in five Southern States there was a slight increase out of line with the otherwise consistently downward trend.

5. The factors responsible for the favorable rate since 1938 are unknown but may be due to better economic conditions of the poorer element in the population, allowing better food, more funds for the purchase of antimalarial drugs and for screening homes. Moreover, increased and intensive measures have been taken to suppress or reduce the number of *Anopheles* mosquitoes.

6. While the malaria death rate is a direct reflection only of *falciparum* malaria, indirect evidence indicates that *vivax* malaria has similarly decreased.

7. It is urged that the present reduced trend in intensity and extent of malaria mortality should not produce complacency. Reduced control may allow recrudescences to occur in endemic foci. Moreover, as long as susceptible malaria mosquitoes are allowed to breed, opportunity is afforded for new infections to be introduced from Tropical America and thus "seed" the country with new, possibly more virulent strains of malaria plasmodia.

ACKNOWLEDGMENT

Thanks are due to all directors of health for the forty-eight States and their bureaus of vital statistics for the data from which this analysis has been prepared.

HUMAN MALARIA

H. W. Brown*

School of Public Health
University of North Carolina

Castro (1) describes a quick staining technic for thick blood films. The method consists of rapid drying of the blood film on a hot plate 50°-60° C. followed by Giemsa stain for 3-5 minutes. It is emphasized that the method will not produce good results on blood films over 12 hours old. Field (2) outlines a simple and rapid method of staining malaria parasites in thick blood smears. Using this method a correct diagnosis of the species of malaria may be made in a very high proportion of the cases within 1½ minutes of the preparation of the smear. Michelson and Wilcox (3) have found that a satisfactory thick blood smear malaria preparation can be made by a special staining technic which involves the application of their stain for only 10 minutes. The necessity for thick films being dried for several hours before staining can be avoided according to Field (4) by a brief preliminary treatment with a basic stain. This treatment may be given a thick film as soon as the film ceases to be obviously moist. It prevents the cytoplasm of the leucocytes and malaria parasites from the damaging effects of lysis, frequently encountered in insufficiently dried thick films. Field and LeFleming (5) present the morphology of *P. falciparum*. Colored and black and white plates of the appearance of thick and thin films are presented. These plates in addition to the descriptive matter should make it possible to identify this species of parasite from the thick films.

A further simplification in his buffer precipitation test is described by Wolff (6). Only four drops of blood serum are needed for this test, two drops for the test solution tube and two drops for the control solution tube. The reading may be done after the lapse of from half an hour to two hours and is based on the comparison of the two tubes. The reading is best done by daylight. The value of negative tests is high if the blood be taken at the right time, pref-

*Free use has been made of the Tropical Diseases Bulletin for references not accessible to the reviewer.

erably in the morning before breakfast: the acute feverish period of a malaria attack should be avoided.

A study of malignant malaria, predominantly of the cerebral type, occurring among drug addicts in New York City is reported by Most (7). Infection was acquired by the common use of hypodermic syringes for the intravenous injection of the drug, notably heroin. The series of cases studied by the author exceeded 200: with the exception of one *P. vivax* and one *P. malaria* all were *P. falciparum* infections. Nothing is known as to the origin of the infection strains but it is significant that many of the original cases of this type reported in the United States occurred in seaports or coastal cities and among sailors. Though cases of cerebral type were predominant, cases with gastro-intestinal syndromes occurred and there were two cases of blackwater fever. The cerebral symptoms observed were stupor, coma, occasional convulsions, and neurological signs suggestive of an acute diffuse meningitic or encephalitic process. Death in the majority of fatal cases was due to an overwhelming infection, with diffuse cerebral involvement.

Cole (8) and his co-workers report that an injection of thiobismol (Sodium bismuth thioglycollate) in patients with therapeutic *P. vivax* infections results in 48 hours respite from fever. A single injection will transform a quotidian into a tertian fever and repeated injections arrest clinical therapeutic malaria for long periods.

Shute (9) failed to infect *A. maculipennis* var. atroparvus from English sources with one Indian and three African strains of *P. falciparum*. This English anopheline can be infected with *P. vivax, P. ovale,* and *P. falciparum* of Italian and Roumanian source. Using *Plasmodium vivax* and *Anopheles quadrimaculatus,* Boyd and Jobbins (10) conclude that the incidence of infection as revealed by stomach and gland dissection will be in substantial agreement. His studies also indicate that the development of malaria in mosquitoes is not the cause of their natural mortality.

Stratman-Thomas (11) fed insectary reared *A. quadrimaculatus upon P. vivax* infected paretics. These mosquitoes were then kept at 37.5° C., 32°C., 28° C., 26° C., 24° C., 22° C., 15-17° C., and 1-10° C. The shortest time for the completion of the cycle was 8 days at 28° C. and at 30° C., and the longest time was 38 days at 15-17° C. At all stages of the cycle *P. vivax* was more susceptible to unfavorably high temperatures than to unfavorably low temperatures. Shortly after feeding, an infected *A. quadrimaculatus* was completely sterilized of its infection in two to three hours at 37.5° C:

at 1-10°C. two and half days' exposure was necessary to secure this result. During the growth of oocysts (7 to 13 days after infective feeding), exposure of the mosquito to 37.5° C. for 18-24 hours aborted the development of the parasite: at 1-10° C. 24 days' exposure was necessary to interrupt oocyst development.

When sporozoites were present in the salivary glands, 24 hours' exposure to 37.5° C. inhibited the infectivity of the sporozoites for human inoculation. Adult *A. quadrimaculatus* can survive higher and lower temperatures than can the developmental forms of *P. vivax* which it may harbor.

Stratman-Thomas (12) reports that 268 skin tests in malaria patients failed to give a positive reaction. The antigens consisted of extracts of parasitized red cells prepared in various ways. Using antigens prepared from infected human and monkey blood he likewise failed to secure specific precipitin reactions with the sera of malaria patients. Complement fixation tests gave highly specific results in malaria with antigens prepared from either human or monkey parasitized blood. For complement fixation infected and normal monkey antigen and infected and normal human antigen were used. The monkey antigens and the normal human antigen were prepared after the method of Coggeshall and Eaton. The infected human antigen was prepared from parasites centrifuged from laked heavily parasitized blood cells. The parasite mass was dried in vacuo and ground. A measured amount was rehydrated, frozen, thawed, centrifuged and the supernatant fluid was used as antigen. Sixty-two patients with malaria and thirty-five normal persons were tested. Infected monkey and infected human antigens gave identical results. Patients with malaria parasites in their blood at the time the sera were taken gave a significantly higher number of positive reactions than those with no parasites. Patients having fever before sera were taken gave significantly more positive reactions than those who had not had fever. In short, the complement fixation test yields highly specific results in malaria with antigens prepared from either human or monkey parasitized blood. Coggeshall (13) finds that serum from human patients who had recovered spontaneously from therapeutic *Plasmodium knowlesi* infections when incubated one half hour with *P. knowlesi* parasites markedly affected their infectability. Injection of such serum-parasitic mixtures into monkeys resulted in either no infection or light infections followed by recovery. Control monkeys injected with normal human serum__*P. knowlesi* mixtures exhibited acute

fatal malaria infections. Mulligan, Russell and Mohan (14) find that malaria sporozoites secured from mosquitoes salivary glands are agglutinated by high dilutions of homologous malarial sera (1-1000 to 1-65,000). Normal and heterologous malarial sera agglutinated sporozoites in saline solutions not exceeding 1/128. Their studies included the following species of malaria: *P. kallinaceum, P. cynomolgi, P. knowlesi, P. inui, P. praecox, P. falciparum* and *P. malariae.*

Young, Stubbs and Coatney (15) report a high degree of synchronicity for *P. malariae* in Negroes. The different growth stages consumed the following length of time: trophozoite 54.2 hours; young schizonts 10.4 hours and segmenters 7.4 hours. Young, Coatney and Stubbs (16) found that the segmenter peak time of *P. malariae* in Negro paretics was altered by activity of the host. Patients with the usual day activity and night resting period exhibited their segmenter peak time at 9 A. M. Reversal of activity to night and rest by day resulted in a 9 P. M. segmenter peak time. Return to a normal schedule resulted in a return to the 9 A. M. segmenter peak time. Night did not appear to affect the malaria parasite's periodicity.

Zwemer, Sims, and Coggeshall (17) have attempted to study the toxic substance released during the rupture of merozoites from the malaria infected red cell. Since the red cells contain twenty times as much potassium as plasma it is possible that potassium is the toxic substance. To test this hypothesis studies were made on thirteen patients undergoing malaria therapy with *P. vivax.* Additional studies were made on rhesus monkeys inoculated with *P. knowlesi.* It was shown that in malaria of man and monkey there is an increase of potassium in the plasma and serum which may come from red cells at the time of sporulation of the parasite, or may result from the reaction of foreign protein or toxin on body cells in general. This marked increase in potassium is accompanied by chills and precedes the rise in temperature. The base line potassium values tend to increase with progress of the malaria infection. It is pointed out that marked involvement of the adrenal cortex in some fatal malaria cases is compatible with a disturbance in potassium metabolism.

Raman (18) reports an infection with *P. ovale* in a patient in India. The parasite had the characteristic appearance of *P. ovale* but the photomicrographs are not sufficiently clear to make a definite diagnosis. Sinton (19) has made a study of the efficiency and

nature of the immunity acquired as the result of infections induced by *P. ovale* sporozoite inoculations as compared with those by trophozoite infections. The immunity following infections induced by sporozoites is more effective than that following infection induced by trophozoites. The immunity produced appears to be operative largely, if not entirely, against the trophozoites and not against sporozoites. Repeated successive inoculation of *P. ovale* into human beings were found by Sinton (20) to produce progressively higher degrees of resistance to subsequent reinoculations. In this respect *P. ovale* resembles the other species of human malaria. The anti-toxin element of the immunity as evidenced by diminished febrile response to infection appears to be developed more rapidly than the anti-parasitic element. However, in the absence of renewed infection the anti-parasitic immunity appears to be more durable than the anti-toxin element.

Boyd (21) made careful observations on a number of strains of *P. vivax* and *P. falciparum* employed in infecting anopheles and human beings. He concludes that there are well fixed strains or races of malaria. The antigenic character of one strain of *P. vivax* persisted after the completion of 40 sexual cycles in the mosquitoes. Certain strains or races may exhibit slight morphological differences. A local strain of malaria parasite may or may not be specially suitable for infecting the anopheles with which it is associated in nature and conversely these anopheles may or may not be highly susceptible to exotic strains of the parasite. A comparison of artificially and naturally induced *P. malariae* infections is also reported by Boyd (22). The incubation period subsequent to natural inoculation has varied from 4-5 weeks, with a lag of from three to twelve days between the first detection of parasites and the clinical onset. Subsequent to artificial inoculation it has usually been shorter, and but rarely has the clinical onset preceded the detection of parasites. The attacks including recurrences subsequent to natural inoculation have in whites had a mean duration of 170 days and in Negroes of 76 days. Subsequent to artificial inoculation the mean duration of uninterrupted attacks in whites has been 81.2 days and in Negroes 53 days. The clinical course following natural inoculation is of much simpler pattern that that observed subsequent to artificial inoculation. The paroxysms are more commonly a simple quartian and show a high degree of constancy in the hours of their recurrence. On the other hand those recurring subsequent to artificial inoculation show a much greater complexity and irregularity.

The infections resulting from artificial inoculation (infected blood) with *P. vivax,* Boyd (23) finds, differ from those resulting from natural (mosquito) inoculations. With a sufficiently heavy inoculum of trophozoites, the incubation period may be altogether suppressed. Renewed activity after cessation of the artificially induced primary attack has only been observed to occur within eight weeks of the former event. The attacks in the artificially inoculated recipients have generally been shorter than those experienced by the donors regardless of whether the donor's infection was active or inactive at the time the inoculum was secured. Boyd (24) also reports that the dosage of sporozoites of *P. vivax* with which a susceptible person is inoculated, as deduced from the quantitative infection of a lot of mosquitoes and the number of specimens of such a lot employed for an inoculation, exerts a significant effect on the subsequent infection. If the dosage is small, the proportion of unsuccessful inoculations will be high. The duration of the incubation periods tends to vary inversely with the dose of sporozoites received. The duration of the clinical attack apears to vary directly with the dose of sporozoites, and inversely with the length of the incubation period. Renewed activity is most frequent following induced termination of attacks produced by heavily infected mosquitoes. There is some tendancy for patients inoculated with such mosquitoes to experience a greater number of severe paroxysms than do those inoculated with lightly infected mosquitoes.

Reticulocyte counts on the blood of hookworm infected individuals have been made by Brown and Otto (25) in an attempt to ascertain whether or not the presence of this parasite influences malaria infections. They found no differences in reticulocyte percentages in hookworm infected and worm free children. They conclude that chronic hookworm infection does not produce a reticulocytosis which would favor malaria infection. Children infected with both malaria and hookworm had slightly higher reticulocyte counts than those infected with hookworm only. A case of typhoid fever and another of meningococcal cerebrospinal meningitis were found by Cannata (26) to activate unsuspected malaria infections.

BIBLIOGRAPHY

1. Castro, G. J. Lab. and Clin. Med., 25 (12): 1308-1310 (1940).
2. Field, J. W. Trans. Roy. Soc. Trop. Med. & Hyg., 34: 195 (1940).
3. Michelson, L. & Wilcox, A. Public Health Rep. 55: 1221 (1940).
4. Field, J. W. Trans. Roy. Soc. Trop. Med. & Hyg., 33: 635 (1940).

5. Field, J. W. & LeFleming, H., Trans. Roy. Soc. Trop. Med. & Hyg., 33: 507 (1940).

6. Wolff, E. K. Indian Med. Gaz., 75: (9): 517-519 (1940).

7. Most, H. Trans. Roy. Soc. Trop. Med. & Hyg., 34: (2): 139-172 (1940). Amer. Pub. Health Jour., 30 (4): 551-567 (1940).

8. Cole, H. N. et al. J. Amer. Med. Assoc., *115* (6): 422-426 (1940).

9. Shute, P. G. J. Trop. Med. & Hyg., *43* (13): 175-178 (1940).

10. Boyd, M. F. & Jobbins, D. M. Amer. J. Trop. Med., *20* (3): 423-429 (1940).

11. Stratman-Thomas, W. K. Amer. J. Trop. Med., *20* (5): 703-715 (1940).

12. Stratman-Thomas, W. K. & Dulaney, A. D. Amer. J. Trop. Med., *20* (5): 717-725 (1940).

13. Coggeshall, L. T. J. Exper. Med., 72 (1): 21-31 (1940).

14. Mulligan, H. W. Russell, P. F., & Mohan, B. N. Jour. Malaria Inst., India, 3:513-524 (1940).

15. Young, M. D., Stubbs, T. H. & Coatney, G. R. Amer. Jour. Hyg., *31* (Sec.C):51-59 (1940).

16. Young, M. D. Coatney, G. R., & Stubbs, T. H. Amer. Jour. Hyg., 32 (Sec.C):63-70 (1940).

17. Zwemer, R. L., Sim, E. A. H. & Coggeshall, L. T. Amer. J. Trop. Med., *20* (5):687-701 (1940).

18. Raman, T. K. J. Indian Med. Assoc., *9* (12):583-585 (1940).

19. Sinton, J. A. Trans. Roy. Soc. Trop. Med. & Hyg., 33:439 (1940).

20. Sinton, J. A. Trans. Roy. Soc. Trop. Med. & Hyg., 33:585 (1940).

21. Bold, M. F. Amer. Jour. Trop. Med., *20*:69 (1940).

22. Boyd, M. F., Amer. Jour. Trop. Med., *40*:249 (1940).

23. Boyd, M. F., Amer. Jour. Trop. Med., *40*:269 (1940).

24. Boyd, M. F. Amer. Jour. Trop. Med., *40*:279 (1940).

25. Brown, H. W. & Otto, G. F. Amer. Jour. Hyg., 33(Sec.D): 22 (1940).

26. Cannata, R. Pediatria, 48:113 (1940).

A Review of Recent Work on the Parasitology of Simian Malarial Infections and Simian Plasmodia.*

J. C. Swartzwelder **

New Orleans, Louisiana

The following report summarizes briefly the parasitology of malaria as related to simian infections and simian plasmodia from the available literature which was published in 1940 and some which appeared in 1941. Experimental chemotherapy of simian infections is not included, since that subject is covered by another review. In the preparation of this report, the Tropical Diseases Bulletin and Biological Abstracts have been invaluable and used freely for references unavailable to the reviewer.

Singh and Singh[1] demonstrated the protective value of immune serum in treating *P. knowlesi* infections in monkeys, adding confirmation to the work of Coggeshall and Kumm who had shown that the serum of rhesus monkeys with chronic *P. knowlesi* infections conferred a passive immunity upon normal monkeys. It was found,[1] however, that while effective protection was afforded against the fatal effects of *P. knowlesi* in some of the monkeys, in others no protective value was apparent except for prolongation of the infection. The best protection was afforded when the administration of the immune serum was instituted at the time of inoculation. Substantial evidence has been presented by Coggeshall[2] that protective antibodies occur in the serum of individuals who have recovered from *P. knowlesi* infections. Protection tests were carried out by incubating *P. knowlesi* parasites with sera of recovered individuals and injecting varying numbers of these parasites intra-abdominally into normal *rhesus* monkeys. The sera of recovered patients exerted a definitely protective effect, while control or normal serum did not alter the course of the usually fatal infection in

*Read before the National Malaria Committee, meeting conjointly with the Southern Medical Association, Thirty-fifth Annual Meeting, St. Louis, Missouri, November 10-13, 1941.

*A report to the National Malaria Committee from the Sub-committee on Medical Research.

**Department of Preventive Medicine and Public Health, Louisiana State University School of Medicine, New Orleans.

monkeys. Although complement fixing antibodies were also demonstrated, there was no evidence to indicate their identity with the protective antibodies.

In studies of immunity in simian malaria as evidenced by results of superinfection, Singh and Singh[3] noted that a chronic infection with *P. knowlesi*, *P. inui* or *P. cynomolgi* produced an effective immunity to homologous super-infections, but failed to prevent or alter the course of reinfection with a different species. This indicated an absence of cross immunity in the three species of monkey plasmodia. The immunity to homologous superinfection in *P. knowlesi* infections was effective for at least four months after parasites disappeared from peripheral blood and diminished with the longevity of the parasite-free period, while in *P. inui* and *P. cynomolgi* infections an effective immunity persisted for a longer period of time.

The experimental studies of Mulligan, Sommerville and Swaminath[4] with *P. cynomolgi* and *P. knowlesi* in monkeys indicate that cellular and humoral agencies in the mechanism of malarial defense are definitely correlated and so closely interdependent that under the conditions of their experiments, a full measure of one was relatively ineffective in the absence of an adequate measure of the other. This significant conclusion is based on their findings that (1) attempts to modify the course of malarial infections in normal monkeys by administration of immune sera from homologous infections yielded only partially successful results in the case of *P. knowlesi* and had no effect on the course of *P. cynomolgi* infections; (2) the course of *P. knowlesi* infections in splenectomized monkeys was unaffected by the administration of homologous immune sera; however, (3) the administration of homologous immune sera was very effective in controlling *P. knowlesi* infections in rhesus monkeys in which the lymphoid-macrophage system had been adequately stimulated by previous infection with *P. cynomolgi.* According to Mulligan, Sommerville and Swaminath[5] splenectomy did not impair the natural immunity existing in simian malarial infections, but it did interfere with the acquired immunity. Their studies indicate that in addition to the cellular mechanism of immunity, which is centered in the spleen, and the humoral agencies, a third factor in immunity, i. e., an inherent quality of the host which is inimical to the development and multiplication of the parasites, is operative.

Repeated weekly inoculations of two monkeys (*M. radiata*)

over a period of six weeks with vaccine prepared from *P. knowlesi* failed to produce any evidence of effective immunity to subsequent infection with the homologous strain of *P. knowlesi* (Shortt and Menon[6]). The use of spleen extracts in controlling malarial infections in monkeys was found to be of less value than immune sera, possibly due to the small amount of extract employed and to the toxic effect of the extracts. The spleen extracts gave best results in *rhesus* monkeys in which the lymphoid-macrophage system had been stimulated by previous infection with *P. cynomolgi*, supporting an earlier conclusion that the utilization of protective humoral antibodies is intimately correlated with the functional state of the cellular defense mechanism (Mulligan, Sommerville and Swaminath[7]). That nutrition is not an important factor in determining the course and severity of primary attacks in monkeys infected with *P. knowlesi* or *P. cynomolgi* was indicated by the studies of Passmore and Sommerville[8]. There was no significant difference in the number of gametocytes in peripheral blood, in the course and severity of the primary attacks and in the results of relapse following splenectomy between two groups of monkeys, one well-nourished and the other in a state of malnutrition. The diets approximated in quality that of two population groups in India.

Zwemer, Sims and Coggeshall[9] have demonstrated that in *rhesus* monkeys inoculated with *P. knowlesi* there is an increase in plasma and serum potassium which reaches its maximum concentration at the peak of sporulation. This significant increase of potassium is accompanied by chills and precedes the temperature rise. It is not certain whether the increase in the plasma potassium is derived from the red blood corpuscles which rupture at the time of sporulation of the parasites or is the result of a foreign protein or toxic reaction on the body cells in general. The findings *suggest* a possible relationship between the disturbance in potassium metabolism and the malarial rigors, for which there is additional compatible evidence. The metabolism of *P. knowlesi, P. inui, P. cynomolgi* and two species of avian plasmodia was studied by Maier and and Coggeshall [10] using a modification of the method of Christophers and Fulton which proved more satisfactory for measuring the oxygen uptake by the malarial parasites than the original technic. The oxygen uptake was proportional to the size of the organism, increasing with development from ring to segmenting stage. *P. knowesi* was found to utilize glucose in its energy exchange and its oxy-

gen uptake was diminished by lack of this substance, confirming Fulton's findings in this detail. Mannose, fructose and glycerol could be used interchangeably with glucose by that parasite. According to Coggeshall[11], *P. knowlesi* consumed about six times as much oxygen as *P. inui* and, whereas sulphanilamide in a concentration less than that required to bring about a complete cure of the *P. knowlesi* infection inhibited the oxygen consumption of *P. knowlesi* almost completely, it had no apparent effect on the respiration of *P. inui.*

Hematological studies in Panamanian monkeys before and after infection with *Plasmodium brasilianum* which were carried out by Taliaferro and Klüver,[12, 13] indicated that the most characteristic change in the blood cells after malarial infection was the increase of mononuclear cells which are phagocytic. The heterophils responded numerically more than any other leukocytes but did not play a significant role in phagocytosis. There was an increase in monocytes, confirming the similar finding in human malaria, but the monocytes did not vary inversely with the temperature as maintained by several workers on human malaria, rather they reached a maximum value just after the maximum temperature. Leukopenia due to heterophils was only occasionally encountered and even then was not marked. The findings gave additional support to the view that the lymphoid hyperplasia augments the mesenchymal reserve from which monocytes and newly formed macrophages arise.

Stratman-Thomas and Dulaney[14, 15] found that antigens prepared from parasitized (*P. knowlesi*) monkey blood were totally unsuited for precipitin tests, since positive reactions occurred with sera of both malaria-free and infected human cases. On the contrary, the complement fixation test yielded excellent results in malarial cases with infected monkeys and infected human antigens. This confirmed the demonstration by Coggeshall and Eaton of a specific complement fixation reaction for malaria employing *P. knowlesi* antigens. Further studies on the complement fixation test in malaria (Dulaney and Stratman-Thomas[16]), employing *P. knowlesi* antigens, demonstrated by absorption tests that the syphilitic reagin and the malaria antibodies appear to be distinct entities, since the antigen of each will remove its corresponding antibody without affecting the reactivity of the serum to the other antigen. Employing the technic described by Eaton, in which parasitized red cells of monkeys infected with *P. knowlesi* served as antigen, Singh and

Singh[17] carried out agglutination reactions with sera from monkeys harboring three species of simian plasmodia. They found that agglutination of the infected red cells of the *P. knowlesi* antigen occurred only between sera from monkeys suffering from chronic infections with *P. knowlesi*, but not with sera from monkeys infected with *P. cynomolgi* and *P. inui*, indicating an absence of cross agglutination. Mulligan, Russell and Mohan [18, 19] found that normal sera and heterologous malarial sera from monkeys suffering from acute and chronic infections with *P. knowlesi, P. cynomolgi* and *P. inui* agglutinated the sporozoites of the avian plasmodium, *P. gallinaceum*, in low dilutions, not exceeding 1/128. In contrast, homologous malarial sera from fowl infected with *P. gallinaceum* agglutinated sporozoites of that species in dilutions ranging from 1/1000 to 1/65000, suggesting that the sporozoite agglutination, at least in high dilutions, is probably a specific reaction.

Shortt and Menon[20] have reported that monkeys can be readily infected with *P. knowlesi* by the oral route. The technic consisted simply of dropping defibrinated blood from heavily infected animals into the open mouths of the normal monkeys, care being taken not to touch the mouths of the animals when dropping the blood and that there were no obvious lesions of the mucous membranes of the mouth. Coggeshall[21] succeeded in infecting *Anopheles quadrimaculatus* with an oriental monkey malarial plasmodium, *P. cynomolgi*, thus demonstrating clearly that the natural association of a mosquito host and the malarial parasite is not necessary for susceptibility, since the geographical distribution of *A. quadrimaculatus* is confined to the United States. Attempts to infect *A. quadrimaculatus* and *A. punctipennis* from *P. knowlesi* infections in man met with failure. According to Rodhain and Van Hoof,[22] *Plasmodium kochi*, the common malarial parasite of Central African monkeys, failed to develop in *Anopheles maculipennis, Aedes aegypti*, or *Culex pipiens*. On the contrary *P. cynomolgi* developed very readily in *A. maculipennis*, which also served as a fairly suitable host for *P. gonderi* and transmitted infections with this species of plasmodium to monkeys by its bite. Mulligan and Swaminath[23] have reported finding a natural malarial infection with *P. inui* in a young monkey, *Silenus sinicus*, in South India. They state that *P. inui* appears to have a wide distribution in the Middle and Far East, since it has now been recorded from India, Indo-China, Malaya, Java, Sumatra and Borneo. Rodhain and Lassman[24] concluded that the chimpanzee parasite, *Plasmodium schwetzi*, showed a definite

preference for reticulocytes, resembling in this respect *P. vivax* to which it is so similar morphologically. Rodhain[25] recorded an experiment in which the blood of a chimpanzee harboring *P. rodhaini*, which resembles very closely the human parasite, *P. malariae*, was inoculated into a human being suffering from general paralysis. Forty days after the inoculation an attack of fever occurred, at which time malarial parasites similar to the inoculated organisms were present in blood films.

REFERENCES CITED

[1]Singh, J. and Singh, H.: Passive Immunity in Monkey Malaria. Jour. Mal. Inst. India, 3, 137-142, 1940.

[2]Coggeshall, L. T.: The Occurrence of Malaria Antibodies in Human Serum Following Induced Infection with *Plasmodium knowlesi*. Jour. Exper. Med. 72, 21-31, 1940.

[3]Singh, J. and Singh, H.: Observations on Immunity in Monkey Malaria as Evidenced by the Results of Superinfection. Jour. Mal. Inst. India, 3, 99-114, 1940.

[4]Mulligan, H. W., Sommerville, T. and Swaminath, C. S.: Cellular and Humoral Agencies in Defense Against Malaria. Jour. Mal. Inst. India, 3, 563-579, 1940.

[5]Mulligan, H. W., Sommerville, T. and Swaminath, C. S.: The Effects of Splenectomy on Natural and Acquired Immunity in Monkey Malaria. Jour. Mal. Inst. India, 3, 591-601, 1940.

[6]Shortt, H. E. and Menon, K. P.: Attempt to Produce Active Immunity to Malaria in Monkeys by Vaccination with Parasitic Substance. Jour. Mal. Inst. India, 3, 191-193, 1940.

[7]Mulligan, H. W., Sommerville, T. and Swaminath, C. S.: Attempts to Control Malarial Infections in Monkeys by the Administration of Spleen Extracts. Jour. Mal. Inst. India, 3, 581-590, 1940.

[8]Passmore, R. and Sommerville, T.: An Investigation of the Effect of Diet on the Course of Experimental Malaria in Monkeys. Jour. Mal. Inst. India, 3, 447-455, 1940.

[9]Zwemer, R. L., Sims, E. A. H. and Coggeshall, L. T.: The Plasma Potassium Level During Malaria Infection in Monkeys and Man. Amer. Jour. Trop. Med., 20, 687-701, 1940.

[10]Maier, J. and Coggeshall, L. T.: Respiration of Malaria Plasmodia. Jour. Infect. Dis., 69, 87-96, 1941.

[11]Coggeshall, L. T.: The Selective Action of Sulfanilamide on the Parasites of Experimental Malaria in Monkeys *In Vivo* and *In Vitro*. Jour. Exper. Med., 71, 13-20, 1940.

[12]Taliferro, W. H. and Kluver, C.: The Hematology of Malaria (*Plasmodium brasilianum*) in Panamanian Monkeys. 1. Numerical Changes in Leucocytes. Jour Infect. Dis., 67, 121-161, 1940.

[13]Idem: The Hematology of Malaria (*Plasmodium brasilianum*) in Panamanian Monkeys. 2. Morphology of Leucocytes and Origin of Monocytes and Machophages. Jour. Infect. Dis., Ibid. 67, 162-176, 1940.

[14]Stratman-Thomas, W. K. and Dulaney, A. D.: Immunologic Studies in Malaria

with Special Reference to the Diagnosis of Malaria. Amer. Jour. Trop. Med., *20*, 717-725, 1940.

[15]Dulaney, A. D. and Stratman-Thomas, W. K.: Complement Fixation in Human Malaria. 1. Results Obtained with Various Antigens. Jour. Immunology, *39*, 247-255, 1940.

[16]Idem: Specific Nature of Complement Fixing Antibody in Malaria as Demonstrated by Absorption Tests. Proc. Soc. Exper. Biol. and Med., *44*, 347-349, 1940.

[17]Singh, J. and Singh, H.: Agglutination Reactions with *Plasmodium knowlesi.* Jour. Mal. Inst. India, *3*, 53-66, 1940.

[18]Mulligan, H. W. and Russell, P. F.: Agglutination of Sporozoites of *P. gallinaceum*. Preliminary Note. Jour. Mal. Inst. India, *3*, 199, 1940.

[19]Mulligan, H. W., Russell, P. F., and Mohan, B. N.: Specific Agglutination of Sporozoites. Jour. Mal. Inst. India, *3*, 513-524, 1940.

[20]Shortt, H. E. and Menon, K. P.: Experimental Production of Monkey and Avian Malaria by an Unusual Route of Infection. Jour. Mal. Inst. India, *3*, 195-198, 1940.

[21]Coggeshall, L. T.: Infection of *Anopheles quadrimaculatus* with *Plasmodium cynomolgi*, a Monkey Malaria Parasite, and with *Plasmodium lophurae*, an Avian Malaria Parasite. Amer. Jour. Trop. Med., *21*, 525-530, 1941.

[22]Rodhain, J. and Van Hoof, T.: Contribution a l'Etude des *Plasmodium* des Singes Africains. Le Comportement Different des *Plasmodium gonderi* and *Plasmodium kochi* chez les Moustiques. Bull. Soc. Path. Exot., *33*, 107-113, 1940.

[23]Mulligan, H. W. and Swaminath, C. S.: Natural Infection with *Plasmodium inui* in *Silenus sinicus* from South India. Jour. Mal. Inst. India, *3*, 603-604, 1940.

[24]Rodhain, J. and Lassman, P.: Le Comportement de *Plasmodium schwetzi* (Brumpt) du Chimpanze vis-a-vis de Reticulocytes. Ann. Soc. Belge de Med. Trop., *20*, 83-90, 1940.

[25]Rodhain, J.: Les Plasmodiums des Anthropoides de l'Afrique Centrale et Leurs Relations avec les Plasmodiums humains. Receptivite de l'Homme au *Plasmodium malariae* (*Plasmodium rodhaini* Brumpt) du Chimpanze. C. R. Soc. Biol., *133*, 276-277, 1940.

A REVIEW OF RECENT WORK IN AVIAN MALARIA*

MARTIN D. YOUNG**

U. S. Public Health Service

This is an attempt to summarize briefly most of the research which was published in 1940 and some that has appeared in 1941 on the avian malarias. Use has been made of abstracting journals for references not available to the reviewer.

The exoerythrocytic (E-E) phase of malaria received much attention. There is still much diversity of opinion as to the role, development, and importance of these bodies.

In 3 serial transfers of a Mexican strain *P. cathemerium* involving 8 canaries, Hewitt (1940b) found the E-E forms in only 3 birds and concluded their appearance to be biologically unstable. Wolfson (1940b) reports that the wood-thrush strain of *P. cathemerium* produces E-E forms in canaries but not in ducks. In *P. relictum* var *matutinum*, Manwell (1940) found that of 18 canaries infected by blood or mosquito bites, E-E bodies were found in 9, with a preponderance in the brain while the erythrocytic schizonts localized in internal organs, principally the liver. de Ritis (1940) observed that fowls dying in the 4th or 5th week of infection with *P. gallinaceum* showed E-E schizonts while those dying after 5 weeks did not, although blood from the latter produced E-E infections. Quinine was effective against erythrocytic parasites but not against the E-E forms. Jacobi (1940) could find no E-E forms of *P. gallinaceum* between the 10th and 74th day of infection. Dobler (1941) records the appearance of E-E forms in canaries with the matinal strain of *P. relictum* after passage through ducks. Previously, no E-E bodies had been found in the canaries. The E-E derivative was more pathogenic than the original. Schulemann & Knoche (1941) by injections of colloidal palladium influenced the course of infection of fowls with *P. gallinaceum* in the direction of the development of E-E forms and a decrease of erythrocytic forms. Mu-

---

*Partial report of The Sub-committee on Medical Research of the National Malaria Committee for the 1941 meeting in conjunction with the Southern Medical Association.

**Pathologist, Malaria Research Laboratory, Malaria Investigations, National Institute of Health, located at the South Carolina State Hospital, Columbia, South Carolina.

drow (1940) found E-E forms developed in 30 percent of 150 fowls infected with *P. gallinaceum.* These forms were more common in fatal infections and were in greater number in sporozoite infections. Probably a correlation exists between the E-E forms and the death-rate.

Several theories have been offered to explain the development and role of the E-E forms. Taddia & Viero (1940) suggest that these forms do not represent an essential stage in the life-cycle but are accidental occupants of the reticulo-endothelial cells (by phagocytosis).

Missiroli (1940) advocates that inoculated sporozoites complete a developmental cycle extra-cellularly before infecting the tissue cells or erythrocytes.

Still another group, Kikuth & Mudrow (1940), Schulemann & Spies (1940), Raffaele (1940), Shortt, Menon, & Iyer (1940), believe that the sporozoites go through an "intermediate" schizogony in endothelial cells and after one or more generations produce "hemotropic" merozoites. Shortt et al suggest that between relapses the disease may exist as a low grade infection of the reticulo-endothelial system.

That the E-E forms may originate from the erythrocytic parasites and/or vica versa is supported by the work of Villabos (1940), de Ritis (1940), Coulston & Manwell (1941), Schulemann & Knoche (1941), and Zain (1941). Zain as a result of filtration experiments concluded that the mature schizonts in erythrocytes may be considered as the original forms of E-E stages. Coulston & Manwell produced infections with single parasites of the erythrocytic cycle and found E-E bodies after several subinoculations.

Lumsden & Bertram (1940) observed for *P. gallinaceum* the following: length of asexual cycle, 36 hours; gametocytes appear as early as asexual forms, are produced in broods, mature in 24 hours following schizogony, and are about one-half of the total number of parasites. Beltran & Larenas (1940) found the length of the asexual cycle of this parasite to vary from 36 to 42 hours, the latter time being more frequent. Also, the synchronicity was high. The parasite mortality was high but not as much so as reported for other avian plasmodia. Mudrow (1940) found the incubation periods of this parasite for infected blood and sporozoite to be the same (8.3 and 8.5 days) in 150 chickens. de Ritis (1940) in *P. gallinaceum* found the shortest incubation periods resulted from intravenous injections, intermediate from intramuscular, and the long-

est periods from subcutaneous. Jacobi (1940) found parasites in the blood a few minutes after intramuscular injections. Older segmenting forms were better able to develop after intravenous injections than other stages. Citrated blood remained infective for 4 days at room temperature. Blood from a hen with an infection of 18 months duration was still infectious.

Coatney (1940) found that *P. relictum* in pigeons showed a relatively high synchronicity and a marked periodicity of 27 hours. Fulton (1940) found the Italian strain of *P. relictum* to have an incubation period of 5.6 days after blood inoculation and 7 days from mosquito infections; an asexual cycle of 24 hours with segmentation peak at 5:00 P. M.; the acute infection period was over 12 days after inoculation. Parasites were found in blood for from 2 to 3 weeks; relapses were rare. Manwell (1940) investigating *P. relictum* var. *matutinum* found it differed from the *P. relictum* proper by having a strict 24 hour periodicity. The strain is physiologically distinct. The mean number of merozoites per segmenter is about 16. Transmission was effected by *Culex pipiens*.

Terzian (1940a) studying *P. lophurae* found a low synchronicity. The asexual cycle was 48 hours in length. There was no difference in the number of parasites between the peripheral circulation and internal organs. Virulence was maintained by rapid trasfer. Velick & Scudder (1940) found that in *P. cathemerium* infections in canaries, chickens, and ducks, the potassium approached (increased) a toxic level at sporulation. This was not found in the low-synchronicity *P. lophurae* infections in chickens.

Hegner & West (1941a) studied the modifications of 2 strains of *P. cathemerium* when transferred from canaries to ducks. The prepatent period of the Wolfson strain was from 3 to 5 days in canaries and from 3 to 8 days in the ducks; in the H-H strain, from 8 to 14 days in canaries as against 11 days in ducks. In canaries the total parasite counts were higher, the synchronicity higher, the pathology greater, the symptoms more severe, the relative percentage of gametocytes lower, the number of merozoites greater, the segmenters larger, and the segmentation earlier (5:00 A. M. against 9:00 P. M.) than in the ducks. In the latter, the macronucleus displaced the red cell nucleus less often than in canaries.

Hegner & West (1941b) were able to produce infections in day old chicks with the W and H-H strains of *P. cathemerium.* The asexual cycle lengthened from 24 hours in canaries and ducks to 48 hours and the segmentation occurred at 9:00 A. M. The num-

ber of merozoites in chick infections was smaller than in canaries or ducks.

Terzian (1941b) found that *P. lophurae* in chicks produced about the same pathology as other avian malarias in canaries. The weight of the chickens was related to the resistance to parasites, the heavier birds being more resistant. Hewitt (1941a) studying the distribution of *P. relictum* and *P. cathemerium* parasites in the visceral organs and peripheral blood concluded that no organ or tissue in the body may be regularly predicted to exhibit greater number of parasites than occur in any other part of the body concomitantly.

In *P. cathemerium* infections, Hegner (1940) showed that the destruction of parasites increased progressively during the onset which indicates that immunity is gradually acquired and does not appear suddenly at the crisis. Gingrich (1941a) believes that phagocytosis is not the main factor in natural immunity; but it is an active process and a major factor in acquired immunity.

Gingrich (1941b) produced a high degree of immunity to *P. cathemerium* by 12 intravenous injections of 1 cc. of 50 per cent suspension of red cells, 40 to 60 per cent parasitized. Vezzoso (1940) could immunize fowls against *P. gallinaceum* with various doses of serum from a natural infection.

Manwell & Goldstein (1940) immunized 18 out of 32 canaries against *P. circumflexum* by giving from 7 to 9 injections of serum from chronic infections. Immune serum was observed to agglutinize parasitized red cells. Taliaferro & Taliaferro (1940) in *P. lophurae* found a marked immunity to superinfection during latency following the primary infection. There was a well-defined age immunity which was passively transferred to normal chickens from latent infections by giving the serum for 9 days.

Mulligan & Russell (1940) report that sera of normal animals and of animals suffering from acute and chronic infections with heterologous species of Plasmodium agglutinated the sporozoites of *P. gallinaceum* in relatively low dilutions, while sera of animals suffering from chronic infections with the homologous Plasmodium agglutinated sporozoites of *P. gallinaceum* in very high dilutions. Mulligan, Russell, and Mohan (1940) amplified the above results and also reported agglutination of *P. praecox* (*P. relictum?*) in high dilutions of homologous malarial sera. They believe that sporozoite agglutinations in high dilutions of sera may be a specific reaction.

Shortt & Menon (1940) infected 7 out of 17 chickens by the

oral administration of *P. gallinaceum* blood using from 0.5 to 1.0 cc. Beltran & Larenas (1941a) confirmed this work, obtaining 4 infections out of 44 trials. Working with another species, *P. relictum*, Young (1941) infected 7 out of 10 pigeons by placing from 1 to 8 cc. of infected blood into the crop.

Hurlbut & Hewitt (1941) found one *A. quadrimaculatus* with sporozoites in the salivary glands 22 days after being fed on ducks infected with *P. lophurae*. Coggeshall (1941) had previously followed the development of this parasite to the oocyst stage in the same mosquitoes, 46 per cent of the 56 fed showing infections. Also, he observed low incidences of infections of this parasite in *C. pipiens* and *A. aegypti*.

Rita (1940) could not infect chick embryos with blood containing *P. gallinaceum* but could produce severe infections in newly hatched chicks. Wolfson (1940b) induced *P. cathemerium*, *P. elongatum*, and *P. lophurae* infections in duck embryos. Parasites were found 6 to 16 days after inoculation.

Failure to infect a great horned owl by injections of *P. cathemerium* sporozoites was reported by Beckman & Ota (1940).

Huff (1940) studied the oocysts of several strains of malaria in *C. pipiens* and *A. aegypti*. *P. cathemerium* strains differed in their infectiousness to *C. pipiens* and in the maximum size of the oocysts. Variance of oocyst size between mosquitoes was significantly greater than the variance within mosquitoes. The rate of growth decreases as the oocyst approaches its maximum size.

Later, he (1941) determined that the size of the oocyst is not influenced by (1) degree of infection, (2) activity of or (3) the age of the mosquito and probably not by the humidity. The factors governing the degree of infection seem to be distinct from those governing the rate of growth of the oocysts.

The respiration rate of *P. cathemerium* and *P. lophurae* was determined by Maier & Coggeshall (1941) and it was found that in the former species the oxygen uptake increased as the parasite developed from the ring to the segmenting stage.

Coulston (1941) found the thermal deathpoint of erythrocytic stages of *P. circumflexum* to be 50° C. for 15 minutes or 55°C. for 5 minutes.

Studying *P. cathemerium* and *P. relictum*, Hegner & Dobler (1941) found that an atmosphere high in oxygen content, at normal, increased or decreased pressure, appeared to have only a slight

influence on the infections in canaries and no striking effect on the reticulocyte percentages.

A system of expressing the degree of infection by relating the number of parasites found to the length of time expended and expressing this in + symbols was devised by Beckman (1941).

The incidence of plasmodia infections in nature was studied by the following investigators for the locations indicated: Coatney & Jellison (1940) in Montana; Hewitt (1940c) in Mexico; Beltran (1940) in Mexico.

A new species, *P. durae,* was described from a domestic turkey in British West Africa by Herman (1941). This species is extremely pathogenic to young turkeys. It has elongate gametocytes which frequently assume an oblique polar position in the host cell. Das Gupta & Siddons (1941) described a strain from the Malay Munia which produces 8 to 22 merozoites. It was provisionally named *P. praecox (relictum),* n. var. *muniae.* Wolfson (1940a) reviewed the work on avian Toxoplasma and suggested a grouping of the various forms into 3 types: 1. E-E stages of *Plasmodium;* 2. Uncertain in nature; 3. Identical with mammalian Toxoplasma.

Hewitt (1940a) in a monograph with an extensive bibliography brought the knowledge of avian malaria up-to-date. Reviews of various phases of avian malaria were prepared by Corradetti (1940), Schulemann (1940), Porter & Huff (1940), and Beltran & Larenas (1941b).

REFERENCES

Beckman, H. An experimentally derived method for determining the degree of infection in avian malaria. Amer. Jour. Trop. Med. 21:151-157. 1941.

Beckman, H. & Ota, R. K. Failure to infect the great horned owl with the sporozoites of *Plasmodium cathemerium.* Proc. Soc. Exp. Biol. and Med. 45:477-479. 1940.

Beltran, E. Examen protozoological de la sangre de algunos pajaroa Mexicanos. Ciencio 1:20-21. 1940.

Beltran, E. & Larenas, R. El ciclo esquizogonico en *Plasmodium gallinaceum* Brumpt. Rev. Inst. de Salub. y Enferm. Trop. 1:291-309. 1940.

Beltran, E. & Larenas, R. Produccion de malaria avair con *Plasmodium gallinaceum* par via oral. Rev. Inst. Salub. y. Enferm. Trop. 2:87-94. 1941a.

Beltran, E. & Larenas, R. Estado actual de neustros conocimientos acerca del *Plasmodium gallinaceum* Brumpt, 1935. Rev. Inst. Salub. y Enferm. Trop. 2:95-113. 1941b.

Coatney, G. R. Studies on *Plasmodium relictum* in the pigeon. 1. Periodic phenomena of the asexual cycle. Amer. Jour. Hyg. 31:15-18. 1940.

Coatney, G. R. & Jellison, W. G. Some blood parasites from Montana birds. Jour. Parasit. 26:158-160. 1940.

Coggeshall, L. T. Infection of *Anopheles quadrimaculatus* with *Plasmodium cynomolgi,* a monkey malaria parasite, and with *Plasmodium lophurae,* an avian malaria parasite. Amer. Jour. Trop. Med. 21:525-530. 1941.

Corradetti, A. The significance of the exoerythrocytic cycle of Plasmodia. Jour. Trop. Med. and Hyg. 43:110-113. 1940.

Coulston, F. Thermal deathpoint of the erythrocytic stages of *Plasmodium circumflexum.* Jour. Parasit. 27:365-366. 1941.

Coulston, F. & Manwell, R. D. Single parasite infections and exoerythroctic schizogony in *Plasmodium circumflexum.* Amer. Jour. Hyg. 34:119-125. 1941.

Das Gupta, B. M. & Siddons, L. B. On a *Plasmodium* sp. of the Malay chestnut-bellied Munia (*Munia atricapilla* (Vieill)). Indian Med. Gaz. 76:148-150. 1941.

Dobler, M. Exoerythrocytic schizogony associated with the matinal strain of P. *relictum* after passage through ducks. Amer. Jour. Hyg. 34:49-53. 1941.

Fulton, J. D. The course of *P. relictum* infection in canaries and the treatment of bird and monkey malaria with synthetic bases. Ann. Trop. Med. and Parasit. 34:53-56. 1940.

Gingrich, W. D. The role of phagocytosis in natural and acquired immunity in avian malaria. Jour. Inf. Dis. 68:37-45. 1941a.

Gingrich, W. D. Immunization of birds to *Plasmodium cathemerium.* Jour. Inf. Dis. 68:46-52. 1941b.

Hegner, R. A note on the development of acquired immunity in avian malaria. Amer. Jour. Hyg. 32:24-26. 1940.

Hegner, R. & Dobler, M. Effects of oxygen at different pressures on avian malaria infections. Amer. Jour. Hyg. 34:14-17. 1941.

Hegner, R. & West, E. Modifications of *Plasmodium cathemerium* when transferred from canaries into ducks. Amer. Jour. Hyg. 34:27-39. 1941a.

Hegner, R. & West, E. Transmission of malaria parasites (*Plasmodium cathemerium*) from canaries and ducks to fowls, and their modifications. Amer. Jour. Hyg. 34:40-46. 1941b.

Herman, C. M. *Plasmodium durae,* a new species of malaria parasite from the common turkey. Amer. Jour. Hyg. 34:22-25. 1941.

Hewitt, R. Bird malaria. Monograph No. 15. Amer. Jour. Hyg. 1940a.

Hewitt, R. Exoerythrocytic bodies in canaries infected with a Mexican strain of *Plasmodium cathemerium.* Amer. Jour. Hyg. 31:61-65. 1940b.

Hewitt, R. Studies on blood protozoa obtained from Mexican wild birds. Jour. Parasit. 26:287-295. 1940c.

Hewitt, R. The distribution of avian malaria parasites (*P. relictum* and *P. cathemerium*) in visceral organs as compared with the peripheral blood. Amer. Jour. Hyg. 33:54-68. 1941.

Huff, C. G. Quantitative studies on size, variability and growth rates of oocysts of different strains of avian malaria. Amer. Jour. Hyg. 32:71-79. 1940.

Huff, C. G. Comparative importance of various factors upon the regulation of size of avian malaria oocysts in mosquitoes. Amer. Jour. Hyg. 34:18-21. 1941.

Hurlbut, H. S. & Hewitt, R. Sporozoites of *Plasmodium lophurae,* an avian malaria parasite, in *Anopheles quadrimaculatus.* Publ. Health. Rep. 56:1336-1337. 1941.

Jacobi, L. Zur Biologie und Pathologie des *Plasmodium gallinaceum* (Brumpt). Arch. Exp. Path. u. Pharmakal. 196:623-643. 1940.

Kikuth, W. & Mudrow, L. Die Umwandlung der sporozoiten in die endotheliale phase der malaria-parasiten. Riv Malariol. 19:1-15. 1940.

Lumsden, W. H. R. & Bertram, D. S. Observations on the biology of *Plasmodium gallinaceum* (Brumpt), 1935, in the domestic fowl, with special reference to the production of gametocytes and their development in *Aedes aegypti* (L). Ann. Trop. Med. & Parasit. 34:135-160. 1940.

Maier, J. & Coggeshall, L. T. Respiration of malaria plasmodia. Jour. Inf. Dis. 69:87-96. 1941.

Manwell, R. D. Life-cycle of *Plasmodium relictum* var *matutinum.* Amer. Jour. Trop. Med. 29:859-867. 1940.

Manwell, R. D., & Goldstein, F. Passive immunity in avian malaria. Jour. Exp. Med. 71:409-422. 1940.

Missiroli, A. Sullo svilluppo dei parassiti malarici. Riv. Parassit. 4:69-78. 1940.

Mudrow, L. Klinische und parasitologische befund und chemotherapeutische Ergebnisse bei der Huhnermalaria, Arch. Schiffs u. Tropen. Hyg. 44:257-275. 1940

Mulligan, W. H. & Russell, P. F. Agglutination of sporozoites of *P. gallinaceum.* Preliminary note. Jour. Mal. Inst. India. 3:199. 1940.

Mulligan, W. H., Russell, P. F., & Mohan, B. N. Specific agglutination of sporozoites. Jour. Mal. Inst. India. 3:513-524. 1940.

Porter, J. P. & Huff, C. G. Review of the literature on exoerythrocytic schizogony in certain malaria parasites and its relation to the schizogonic cycle in *Plasmodium elongatum.* Amer. Jour. Trop. Med. 20:869-888. 1940.

Raffaele, G. Ulteriori ricerche sulla fase monogonica primaria dei plasmodidi nell'uomo enegli uccelli. Riv. Malario. 19:193-225. 1940.

Rita, G. Tentativi di infezione dell-embrione di pollo con *Plasmodium gallinaceum.* Riv. Malariol. 19:230-233. 1940.

de Ritis, F. Sul decorso dell'infezione da *P. gallinaceum* (Brumpt) 1935. Riv. Parassit. 4:61-68. 1940.

Schulemann, W. Zur pathologie der malaria. Deut. Med. Woch. 66:253-256. 1940.

Schulemann, W. & Knoche, E. On the problem of the exoerythrocytic developmental forms of *Plasmodium gallinaceum.* I. Naunyn-Schmiedebergs Arch. 197:227-239. 1941.

Schulemann, W. & Spies, K. Zu ursprung und entwicklung der pigmentfrein formen der malaria-parasiten. Deut. Med. Woch. 66:404-405. 1940.

Shortt, H. E. & Menon, K. P. Experimental production of monkey and avian malaria by an unusual route of infection. Jour. Mal. Inst. India. 3:195-198. 1940.

Shortt, H. E., Menon, K. P. & Iyer, P. V. S. The form of *Plasmodium gallinaceum* present in the incubation period of the infection. Ind. Jour. Med. Res. 28:273-276. 1940.

Taddia, L. & Viero, G. Ricerche sulle fassi esoeritrocitiche del *Plasmodium relictum.* Riv. Parassit. 4:45-49. 1940.

Taliaferro, W. H. & Taliferro, L. G. Active and passive immunity in chickens against *Plasmodium lophurae.* Jour. Inf. Dis. 66:153-165. 1940.

Terzian, L. A. Studies on *Plasmodium lophurae* a malarial parasite in fowls. 1. Biological characterisitcs. Amer. Jour. Hyg. 33:1-22. 1941a.

Terzian, L. A. Studies on *Plasmodium lophurae* a malarial parasite in fowls. 2. Pathology and the effects of experimental conditions. Amer. Jour. Hyg. 33:33-53. 1941b.

Velick, S. F. & Scudder, J. Plasma potassium level in avian malaria. Amer. Jour. Hyg. 31:92-94. 1940.

Vezzoso, B. L'immunita passiva nell'infezione da *Plasmodium gallinaceum.* Riv. Malariol. 19:121-129. 1940.

Villabos, E. Sull'origine delle forme esoeritrocitiche nel *P. gallinaceum.* Riv. Parassit. 4:113-116. 1940.

Wolfson, F. Organisms described as avian toxoplasma. Amer. Jour. Hyg. 32:88-97. 1940a.

Wolfson, F. Exoerythrocytic schizogony associated with the wood-thrush strain of *Plasmodium cathemerium* in relation to the species of the host. Amer. Jour. Hyg. 31:26-35. 1940b.

Wolfson, F. Successful cultivation of avian plasmodia in duck embryos. Amer. Jour. Hyg. 32:60-61. 1940c.

Young, M. D. The oral transmission of *Plasmodium relictum* in the pigeon. Publ. Hlth. Rep. 56:1439-1440. 1941.

Zain, H. Zur entstehung der endothelformen der vogelmalaria (*Plasmodium gallinaceum*). Klin. Wschr. 20:176-177. 1941.

ENTOMOLOGICAL WORK DURING 1941 BEARING ON THE MALARIA PROBLEM

(Report of The Sub-Committee on Entomology)

BY STANLEY J. CARPENTER, CHAIRMAN*

THOMAS T. BRACKIN, JR.**

AND

DONALD F. ASHTON***

Prior to 1937 entomological work, bearing on the malaria problem in the malarious areas of the United States, was being done largely by entomologists of the United States Public Health Service, the United States Bureau of Entomology and Plant Quarantine, and entomologists of state agricultural experiment stations who were frequently consulted about matters relating to anopheline mosquito problems. These agencies maintained entomological staffs chiefly for the purpose of conducting research along certain designated lines and therefore very little time could be given in actual field assistance to agencies responsible for malaria control work in the different states.

The establishment of malaria control units in health departments of Southern states in 1937, in which entomologists were included for the purpose of conducting field investigations bearing on anopheline production and control, marked a new era in malaria control work. The report of the Sub-Committee on Entomology in 1939 describes the work being done by the state board of health entomologists.

The recent establishment of National Defense propects in malarious areas has increased the demand for work by existing agencies engaged in mosquito and malaria investigations and control. In most instances state health departments, assisted by personnel assigned to them by the United States Public Health Service, are accepting responsibility for mosquito and malaria control among civilian populations engaged in National Defense enterprises and

*Captain, Sanitary Corps, Entomologist, Camp Joseph T. Robinson, Ark.
**Entomologist, Mississippi State Board of Health, Jackson, Miss.
***Entomologist, North Carolina State Board of Health, Raleigh, N. Carolina.

in areas bordering Army camps and Naval bases. Entomologists representing the different agencies engaged in malaria control work are making valuable contributions to the National Defense Program. The Sanitary Corps of the Army Medical Department has assigned entomologists to certain Army camps in malarious areas in the Southern United States in order that mosquito and malaria control within the camps can be conducted in a more systematic manner. The United States Navy has assigned ten entomologists to active duty and four more are in the process of assuming active duty status for entomological work in malarious areas.

The Sub-Committee on Entomology does not attempt, in this report, to present a complete review of all the entomological work of 1941 bearing on the malaria problem. A questionnaire was prepared and mailed to entomologists engaged in mosquito and malaria control work in state health departments, the United States Public Health Service, the United States Bureau of Entomology and Plant Quarantine, the Tennessee Valley Authority, certain state agricultural experiment stations, and entomologists of the Sanitary Corps of the United States Army. Replies were received from approximately 80% of those to whom questionnaires were mailed. The results obtained by means of the questionnaire have been assembled in this report to show the nature of the work being done by entomologists employed by these agencies.

State Health Departments: Reports were received from seven state health departments in which entomologists are members of the staff of malaria control units. Reports were also received from one entomologist belonging to the staff of a county health unit and two entomologists who were employed by a state health department to make a special mosquito survey during the summer months.

Surveys to determine density and distribution of anopheline vectors and non-anopheline mosquitoes constituted the major work of these state men, from 40 to 100% of their time being spent on this work. Entomologists in 6 states reported mosquito surveys around 27 National Defense projects including Army camps, Naval bases, airports, aviation training schools, and industrial plants engaged in National Defense production. In most cases this work consisted of visits to adult mosquito collecting stations, making larval collections, the operation of mosquito traps for sampling adult mosquito populations, laboratory identification of specimens, the preparation of survey reports, training of inspectors attached to control units, checking the efficacy of larvicidal control operations,

supervision of mosquito control work, and consultation with Army officials on general entomological problems.

Other work reported by these men include epidemiological investigations of malaria cases, the organization and supervision of mosquito control programs in municipalities, the testing of larvicides, the preparation of plans for WPA drainage projects, statewide studies on the occurrence and distribution of the different species of mosquitoes, assistance in making blood slide surveys in schools, organization and supervision of short courses of study on malaria in public schools, and presentation of lectures and motion pictures dealing with mosquito and malaria control.

During the summer of 1941, two entomologists were employed by the Wisconsin State Health Department to make a survey over as much of the state as possible to determine density and distribution of anopheline and non-anopheline mosquitoes. Larval collections and adult collections from resting places and while biting were made during this survey. Thirty-two species of mosquitoes were found during the survey, four of which were *Anopheles*. Approximately 50% of the adult and larval collections were *Anopheles*, 16.3% of which were *Anopheles quadrimaculatus*. The states of Minnesota, Wisconsin, Iowa, Illinois, and Missouri are conducting a cooperative survey along the Mississippi River for determining anopheline densities and malaria prevalence. This cooperative work is being supervised by the State Health Department of Iowa.

Tennessee Valley Authority: Entomologists of the Tennessee Valley Authority are engaged in a diversified program of research on the bionomics of anopheline mosquitoes. These studies include the use of nail kegs as diurnal resting places for *Anopheles quadrimaculatus*, the testing of copper arsenite as an anopheline larvicide, the influence of temperature and humidity on the longevity of *Anopheles quadrimaculatus*, the influence of water temperature on the development of *Anopheles* larvae, and observations on overwintering of *Anopheles quadrimaculatus*.

Approximately 1,200 adult collection stations most of which are barns have been selected for sampling the mosquito population in the Tennessee Valley. On those projects which are already impounded, weekly inspections are made between approximately May 1 and October 1. On those reservoirs which are being prepared for impoundage, inspections are made at intervals of two to four weeks. The identification of all these mosquitoes is subsequently checked by entomologists. During the early and late parts of the

season, when *Anopheles punctipennis* is plentiful in the reservoirs, larval identification is provided by entomologists.

Limnological studies bearing on anopheline breeding are being made in the Tennessee Valley area. These studies include the influence of various chemical and physical factors on anopheline production, the relation of species of vegetation to *Anopheles* breeding and the importance of predators in the control of mosquitoes in the larval stage. In connection with the latter, special attention is being given to the utilization of *Gambusia* in the control of the malaria transmitting mosquito.

A botanist is engaged in the study of possible methods of control of aquatic vegetation which is conducive to anopheline mosquito production in the T. V. A. area. The life histories and distribution of these plants are being determined.

United States Bureau of Entomology and Plant Quarantine: Personnel of the Bureau of Entomology and Plant Quarantine have made investigations of pest mosquitoes in Florida during 1941 with some incidental work on malaria-carrying species. Instruction was given in the biology and identification of mosquitoes in orientation courses for sanitary engineers in a school sponsored by the United States Public Health Service during 1941 at the Marine Hospital, Norfolk, Virginia. Personnel of the Bureau of Entomology are rendering valuable assistance to camp sanitary officers by checking identifications of mosquito specimens.

United States Public Health Service: The entomological personnel of the United States Public Health Service have continued important research work during 1941 to include studies dealing with taxonomy of neotropical anophelines, taxonomy of non-anopheline mosquitoes, and field research on problems of ecology of anophelines.

An experiment to determine range of dispersal of *Anopheles*, in which marked *Anopheles quadrimaculatus* females were recovered at points two and two and one half miles from the point of release, should be of special interest to field workers. Several entomologists have expressed their opinion in personal correspondence that the flying range of *Anopheles quadrimaculatus* may be extended considerably beyond one mile in an area where there is a sudden influx of human population such as occurs with the establishment of an Army camp. They claim that it may be a serious mistake for field men to labor under the belief that control work

should be limited strictly to a distance of one mile around an area for which protection from *Anopheles quadrimaculatus* is desired.

Mosquito surveys of three Army bases and their surroundings were made by entomologists of the United States Public Health Service during 1941 in the Caribbean area.

Entomologists of the Army Sanitary Corps: There were nine entomologists of the Army Sanitary Corps on active duty in Army camps in the Fourth Corps Area and one in the Seventh Corps Area as of June 25, 1941. These men are engaged in entomological work, principally mosquito investigations and control, in Army camps and their immediate surroundings.

After an initial mosquito survey has been made in the Camp area, the work of the camp entomologist consists mostly of checking adult mosquito catching stations, the collection of larvae, operating mosquito traps for sampling mosquito populations, the identification of larvae and adults in the laboratory, studies on special projects relating to the mosquito problem in the camp area and checking the efficiency of mosquito control operations.

Work done by the Camp entomologist provides the Medical Department of the camp with information necessary for organizing and carrying out an effective mosquito control program in the area. Valuable information relative to the mosquito problem in camp areas is being assembled by these men. One camp entomologist reports the collection of 25 species of mosquitoes in traps and a total of 31 species with traps and other means in a camp and its immediate surrounding area during 1941.

Entomologist of The United States Navy: The Navy already has ten entomologists on active duty in malarious areas and it has been stated that sixteen or seventeen entomologists will be on active duty within the next few weeks. These men should be able to render valuable assistance in the protection of Navy personnel against mosquitoes in malarious areas and will undoubtedly be able to assemble valuable data dealing with the different species of mosquitoes found in these different areas.

New Jersey Mosquito Traps: While gathering information on entomological work during 1941 bearing on the malaria problem, we were particularly interested in finding out what entomologists think of the New Jersey mosquito trap as a device for sampling mosquito densities. Reports indicate that these traps are more generally used on projects where the control of both anopheline and culicine mosquitoes is desired. This is especially true of Army camps.

Several of the statements received from entomologists have been selected for your consideration. One entomologists says: "This trap has the advantage of capturing male mosquitoes which are required for taxonomic studies." Another says: "Our experience indicates that the New Jersey trap does not provide us with as useful information as may be obtained from adult collecting stations. The traps possess certain definite limitations. Electric current must be provided either from a power line or from a battery. They require attention twice daily. They are expensive if a large area is to be sampled. In addition, we believe that *Anopheles quadrimaculatus* reacts negatively to light and is not particularly attracted to such traps. It is admitted, of course, that in areas of heavy production, they collect certain numbers of *Anopheles quadrimaculatus* and probably record variations or trends in the population." Another statement from an entomologist reads as follows: "I believe that the efficiency of the traps as anopheline collectors for index purposes will have to be determined by comparison with other collecting methods and tests will have to be made in several regions before this can be decided." Another entomologist says: "The New Jersey trap is an excellent device for sampling mosquito populations." Another opinion reads as follows: "I am convinced that it is a poor indicator of *Anopheles quadrimaculatus* densities."

Another entomologist says: "The New Jersey mosquito trap is an excellent device for capturing adult specimens of some of the rare species and especially male mosquitoes which are seldom taken by other means. Seven mosquito traps were operated in connection with our program of mosquito investigations and control during 1941 and we found them to be just as satisfactory as our hand collecting stations in this area as indicators of *Anopheles quadrimaculatus* densities and for recording trends and variations in the production of these mosquitoes during the entire season."

A thorough investigation of the mosquito problem in the area before the institution of control measures, and measurements of densities, following control work, are necessary for sound operation of a mosquito control program and for determining the degree of benefits derived from such work. The task of working up such information is difficult. We must ardently practice known procedures for sampling mosquito population and we must continually seek more effective devices for accomplishing this important work.

REPORT OF SUB-COMMITTEE ON ENGINEERING

NATIONAL MALARIA COMMITTEE

By

DAVID B. LEE, *Chairman*

Chief Sanitary Engineer
Bureau of Sanitary Engineering
State Board of Health
Jacksonville, Florida

The Sub-Committee on Engineering is charged with studying and reporting the engineering features of malaria prevention and control.

Because of pressure of other work imposed upon the members of this committee due to the present emergency, it has been impossible for the committee to carry out fully the functions which were assigned to it last year. To obtain the information necessary for this report, a questionnaire was mailed to each State in the South, the TVA, and the Santee-Cooper project. The answers to these questionnaires have proven very interesting, but after reviewing the information, it was considered that it would not be desirable to prepare a report which as best could show but a few statistics or details of work along malaria control lines. Therefore, this report will deal with the general analysis of malaria control activities during 1940 and up to September 1, 1941.

Organization

In four States, malaria control is carried on as a cooperative program between the Division of Malaria Control, Bureau of Epidemiology, and the Bureau of Sanitary Engineering. In thirteen States, the Bureau of Sanitary Engineering has complete supervision of the control activities.

Full-time entomologists are working in six States, and three States reported Medical Directors engaged in malaria investigations.

Drainage

Reports received from the Bureaus of Sanitary Engineering of the various State health departments indicate that earthern

ditches still lead all ditch construction in malaria control. Permanent linings were reported in 7 States. The types of permanent linings reported were stone masonry, concrete precast inverts, reinforced concrete monolithic invert, monolithic inverts with sodded banks, brick and mortar, tile drainage and wooden box construction. There is considerable research on precast lining being carried on by several States. There still appears to be a lack of regular maintenance of open ditch construction, and all of us realize that neglected ditches are frequently important sources for the production of Anopheles mosquitoes. The necessity for adequate and proper maintenance of drainage ditches cannot be emphasized too strongly. It is the belief of this committee that in malaria control drainage, it is false economy to construct ditches unless they are designed and constructed so as to provide the longest maintenance-free service. These ditches should be constructed along the same hydraulic principles as storm and sanitary sewers.

Larvicides

The reports indicated that larvicide control work was primarily carried on by agencies other than WPA, except in defense areas.

Diesel #2 or Fuel #2 was the predominant larvicide used, but considerable Paris green is also used. A small amount of phenol larvicide is used, this being preferable because of the small quantities of the material, needed to be transported to the actual site of operation. Minnow (Gambusia) control in impounded water seems to give excellent results where vegetation can be controlled.

Mosquito Proofing The Home

Many States are carrying on a general program of mosquito proofing the homes, and the TVA have shown considerable reduction in malaria incidence through this method of control.

The co-operative work in sanitation between the Farm Security Administration and the State health department has brought about a vast amount of this type of work. Usually the survey of the homes of the FSA tenants shows that they are far beyond economical limits of mosquito proofing.

Efforts have continuously been made to have the WPA remove their regulations prohibiting mosquito proofing of homes with their labor, but no results have been accomplished thus far.

Defense Control Work

During the present emergency, practically all malaria control works, both drainage and larvicide within military reservations are technically the responsibility of the military authorites, and the works outside are under the direction of the State health departments. Actually, most of the military authorities have welcomed the engineers and other health officials to organize and supervise the work within the camps. This has been very helpful in the drainage programs because otherwise the engineers of the health departments would not have been able to coordinate their drainage projects with reference to the drainage in the camps so well. Many ponds and swamps off the reservation must be drained through the reservation, thus making one complete project.

The military authorities are providing funds for both labor and material for work inside the area, but in many places, projects have been submitted and approved using these funds as contribution with the State health departments acting as sponsors. Outside the reservations, the WPA is technically furnishing all labor and material.

Larvicidal programs adjacent to all defense bases were set up during April, under the supervision of the various State health departments, and maintained through funds provided by the U. S. Public Health Service.

This program consisted of mapping, collection of entomological data, and larviciding the one-mile area adjacent to the barracked or building section of the reservation. This in most cases covered the one-mile area outside of the reservation.

On July 1, the financial authority for the operation of their program was transmitted from the U. S. Public Health Service to the Work Projects Administration. Considerable reorganization was necessary in all States, and much valuable time lost. Between July 20 and August 15, the program was resumed and continued through the breeding season with additional technical personnel furnished the States for supervision by the Public Health Service; labor, material, and larvicide, furnished by the WPA.

Recommendations

We should like to suggest that each State keep more accurate cost data—only two States gave cost data on ditching and ditch lining. The National Malaria Committee might well be a clearing-house for cost data on various methods of ditching, types of ditch

lining, sodding, closed systems, larvicidal operations, and other pertinent data. In reading the transactions of the first Annual Conference of State Sanitary Engineers and the U. S. Public Health Service (1920), we were interested to note that much more detailed cost data were reported then than in the present reports.

From the end of the present breeding season to the beginning of the next breeding season, each State might begin the organization for their malaria control program in and adjacent to Defense bases for the ensuing year. This may well be accomplished with the added personnel stationed in the States by the United States Public Health Service.

For each defense base, there should be an accurate map, showing all the existing ponds, wet weather ponds, ditches, streams, swamps, etc. Every potential breeding place, within the mile area of the base.

Locate and mark on a map sufficient catching stations, establish various types of traps for collections of adults.

Begin making entomological investigations early so as to provide accurate information as to when and where the larvicidal crew should begin operation. This will prevent the delays encountered during the past season due to lack of sufficient personnel to quickly organize a program of such magnitude.

Respectfully submitted,

SUB-COMMITTEE ON ENGINEERING

J. C. Clark

J. H. O'Neill

S. L. Davies

C. N. White

David B. Lee, Chairman

National Malaria Committee

November—1941

MALARIA PROGRAM OF THE INTERNATIONAL HEALTH DIVISION OF THE ROCKEFELLER FOUNDATION IN THE UNITED STATES 1941

A. The Foundation has continued its support to the Station for Malaria Research at Tallahassee, Florida, maintained in cooperation with the Florida State Board of Health. This laboratory has continued to furnish the malaria therapy service for the Florida State Hospital, and is engaged in the study of human malaria infections. Papers dealing with: (a) the susceptibility of two strains of quadrimaculatus; (b) the temperature of incubation for anopheles infected with *P. falciparum*; (c) the varying infectiousness of patients infected with vivax malaria; and (d) criteria of immunity and susceptibility in naturally induced vivax malaria, have been submitted. Studies on the characteristics of acquired immunity, the preservation of parasites, gametogeny of the falciparum parasites, and development of pure line strains of *quadrimaculatus,* are being prosecuted. The director, Dr. Mark F. Boyd, has spent considerable time in the Caribbean region, as consultant in the development of malaria programs in which the Division is interested.

The Foundation is further cooperating with the Florida State Board of Health in the creation within that organization of a Division of Malaria Control, which is an outgrowth of the cooperative demonstration carried on during the past four years in Escambia county. The program of this division, is, during its formative period, under the direction of Dr. John E. Elmendorf.

The Foundation has also cooperated with the Georgia State Department of Health in studies of the applicability of pre-cast inverts to antimalarial draining, under the conditions prevailing in that state.

B. It is probable that a significant advance in the control of malaria would result from the discovery of a drug which would sterilize infections in the human host, and thereby reduce the reservoir of carriers infectious for mosquitoes. Such a drug was first found in malaria when Coggeshall showed that sulfanilamide would sterilize *P. knowlesi* infections in rhesus monkeys. Although it was soon found that sulfanilamide was ineffective against human ma-

laria, there remained the possibility that some derivative of sulfanilamide would be effective. Accordingly, a part of the malaria program of the IHD for the current year has been the search for such a derivative. This work is being carried out at the IHD Laboratory in New York, at the Johns Hopkins University Medical School, and at Harvard University. It may be summarized as follows:

1. The IHD Laboratory in New York.

A collection has been made of compounds representative of most of the general classes of sulfanilamide derivatives which have been synthesized. There drugs are being tested against experimental malaria infections, and their comparative effectiveness evaluated. *P. cathemerium* in canaries and *P. lophurae* in ducklings are used for routine testing. Promising drugs are tested further against *P. cynomolgi, P. inui,* and *P. knowlesi* in rhesus monkeys. Recently, *P. gallinaceum* has been imported from Mexico with the permission of the Department of Agriculture, and a test method is being standardized utilizing this infection in chicks.

A drug found to be highly effective against experimental malarias has been given a field trial against naturally occurring infections in Panama. This drug, the di-glucose sodium sulfonate derivative of 4,4'-diamino diphenyl sulfone, was found to be effective against *P. vivax* and *P. falciparum* infections in white and colored patients. A derivative of sulfanilamide, 2-sulfanilamidopyrimidine (sulfadiazine) was also tested and was found to have a definite antimalarial action, which was, however, less than that of the sulfone compound. The methyl derivative of sulfadiazine has shown the greatest effect against laboratory malaria infections thus far found. This drug cannot be used clinically as yet because its toxicity has not been fully evaluated.

It is planned to conduct a large-scale field trial of the most effective drugs found in the laboratory.

In the past, investigation of the prophylactic effect of sulfanilamide derivatives against sporozoites has not been possible. Technical difficulties in the administraton of sulfanilamide derivatives to canaries in such a way as to maintain adequate blood concentrations have prevented the use of *P. cathemerium* for this type of work. These difficulties do not apply in the case of ducks, however, no satisfactory vector has yet been found for *P. lophurae*. Research into the prophylactic effect of drugs will now be carried

on in this laboratory, since blood concentrations of sulfanilamide derivatives are easily maintained in chicks, and an efficient vector of *P. gallinaceum* in *Aedes aegypti* should furnish the necessary sporozoites.

2. The Johns Hopkins University Medical School.

Because there was no information available as to the absorption, excretion, distribution, and toxicity of sulfanilamide derivatives in birds, particularly canaries and ducks, the investigation of these problems was begun at Johns Hopkins in the Department of Pharmacology and Experimental Therapeutics by Prof. E. K. Marshall, Jr., with the support of the IHD. Recently, Prof. Marshall has transferred emphasis from bacterial chemotherapy to malarial chemotherapy and the effect of sulfanilamide derivatives on experimental malaria. For this purpose he has received an additional grant in aid from the IHD.

3. Harvard University.

A grant has been made by the IHD to Prof. L. F. Fieser, Sheldon Emery Professor of organic chemistry at Harvard University. Synthesis of sulfones related to the 4,4'-diamino diphenyl sulfone (di-glucose sodium sulfonate) will be carried on in his laboratory, with the expectation of finding a derivative more effective than this compound.

ACTIVITIES OF THE OFFICE OF MALARIA INVESTIGATIONS, UNITED STATES PUBLIC HEALTH SERVICE, FOR CALENDAR YEAR, 1941

The activities of the Malaria Investigations Office can be summed up under the following headings: Consolidation of offices, Research, States Relation Activities, and National Defense Work.

1. *Consolidation of offices.* In December, 1940 Doctor L. L. Williams, Jr. was given a new assignment as Liaison Officer of the Fourth Army Corps Area, Atlanta, Georgia, and Doctor V. H. Haas was appointed as Medical Officer in Charge. A survey of existing conditions had for some time made it seem desirable to move the Savannah Laboratory to a more advantageous location and in February, 1941 the Washington headquarters office, the Savannah Laboratory and the Memphis sub-office were consolidated in quarters at the University of Tennessee Medical School at Memphis. The work of consolidation and rearrangement of equipment and programs seriously hampered the year's activities.

2. *Research.* It had been planned to make studies of the environmental conditions affecting the production of mosquitoes, as a forerunner of studies of naturalistic control of these insects, but due to the demands of the National Defense program, little progress was made.

The studies of suitable materials for ditch linings was continued and a considerable footage of both precast slabs and cast-in-place linings was installed. A preliminary report of the condition of the experimental linings installed since 1936 was submitted for publication.

In certain States there has been a growing tendency for some years to use commercial phenol larvicides for mosquito control. This larvicide would seem to have certain advantages, the main one being that only a small amount of the larvicide has to be carried into the field and there diluted with water for spraying. Careful experiments were made in the laboratory and in the field with this larvicide as used in mosquito control work.

It was found that the larvicide was less effective than kerosene and that it was definitely harmful to fish. On the basis of these tests phenol larvicides can not be recommended by the Service

as a desirable larvicide for general mosquito control. This work is reported in the August 15, 1941 issue of the Public Health Reports.

A bontanist of the office has been engaged in classifying and studying the botanical life of the Reelfoot Lake Area and has cooperated with the Upper Mississippi Valley States Malaria Survey in studying the flora appearing and which will probably establish itself in the reservoirs incident to the construction of navigation pools on the Upper Mississippi River.

The establishment of a strain of *P. cynomolgi* in monkeys in the laboratory has been accomplished. This plasmodium can be transmitted from monkey to monkey by *A. quadrimaculatus* and will be used in a study of malaria transmission and other associated phenomena.

3. *States Relations.* The office has continued its cooperation with the States in connection with malaria control. Early in the year a technician gave courses of instruction in the technique of the thick film blood examination for malaria parasites under the auspices of the State Health departments of Kentucky, Georgia, and Alabama. In this work a total of 106 technicians were given instruction and 44 were able to devote full time to the courses given.

Engineering assistance was rendered in specific instances to some States but chiefly to the Office of Interstate Malaria Survey of the Upper Mississippi River area. This was the second year of the survey of malaria conditions affected by the construction of navigation dams between St. Louis, Missouri, and St. Paul, Minnesota. The overflow areas adjacent to these impoundments are productive of hordes of *A. quadrimaculatus* mosquitoes and the past season was devoted to determining the extent of the malaria problem involved. The States of Minnesota, Wisconsin, Iowa, Illinois, and Missouri cooperated in this fact-finding survey, in consultation with the Service. Our technician held a course for laboratory technicians in Davenport, Iowa, during July in connection with this activity. A report of the survey is to be submitted at a later date.

4. *National Defense Work.* The office has been called upon to investigate and develop spraying methods for the protection of soldiers engaged in night maneuvers against mosquitoes. At Camp Stewart, Hinesville, Georgia, pyrethrum in alcohol was found to prevent mosquito annoyance when sprayed directly on groups of men engaged in night maneuvers in swamps. This procedure

seemed to be more suitable for the protection of small groups of men than an attempt to render an area mosquito-free by means of "area-spraying," as developed by the New Jersey Anti-mosquito Association.

The personnel assigned to the Louisiana Army maneuvers found the repellant "Sta-way" very effective against mosquitoes. The active ingredient of "Sta-way," Butyl carbital acetate, was also found effective against both mosquitoes and red bugs, the latter insect causing very serious inconveniences to the troops engaged in maneuvers.

Our technician, at the request of Army officials, gave the course in the technique of blood examination for malaria to several classes of army technicians at Fort McPherson, Georgia, from which central point the technicians were assigned to various Army hospitals and relief stations.

A Sanitary Engineer of the office devoted the major portion of his time to the conduct of a mosquito control training school for engineers to be assigned to state and local health departments for the purpose of mosquito and malaria control in national defense areas. This school was conducted as a part of the Orientation Course for Public Health Personnel being conducted at the National Institute of Health.

5. *General.* In September, 1941, the Surgeon General directed Doctor Haas and Mr. Johnson of the office to proceed to China for a period of approximately one year in connection with malaria and other disease control during the construction of the Yunnan-Burma railroad. During this period Sanitary Engineer J. L. Robertson, Jr., will be in temporary charge of the office of Malaria Investigations.

STATEMENT FOR THE NATIONAL MALARIA SOCIETY*
TENNESSEE VALLEY AUTHORITY

During the season of 1941, the Tennessee Valley Authority had under operation six main river reservoirs with a shoreline of approximately 3500 miles and six tributary reservoirs with a shoreline of about 1000 miles. Under construction are three main river reservoirs and five tributary reservoirs with approximate shorelines of 3200 and 600 miles, respectively. The accelerated construction schedule, because of national defense needs, calls for completion of these reservoirs by January 1, 1944, or before that time. This will result in the approximate shorelines of 6700 miles in main river reservoirs and 1600 miles in tributary reservoirs, a total of 8300 miles.

Anophelism and Water Management

The need for conserving water and operating the reservoirs to produce a maximum of power for national defense made it impossible to provide favorable water level fluctuation schedules for malaria control. During the latter part of May and June, the storage in the main river reservoirs was used for the generation of electricity. This drawdown resulted in effective mosquito control with a very limited use of larvicides. Heavy rains beginning early in July resulted in high stream flows and the main river reservoirs were maintained above normal pool elevation during the greater of of the month. In spite of intensive application of larvicides, extensive production of *A. quadrimaculatus* resulted. Some filling occurred in the two major storage reservoirs, Norris and Hiwassee, so that it was necessary to carry on larvicidal operations in these reservoirs which is unusual. Early in August general drawdowns were again begun, resulting in effective control with reduced use of larvicides.

Reservoir Improvement

A recent development in the specifications for marginal clearing for malaria control is low stumping in flat areas. This requires

*Prepared by the Sub-Committee on Malaria Prevention Activities.

cutting stumps to a height of not over four inches in order to facilitate the use of mowing machines in the annual rebrushing and conditioning of the marginal areas within the zone of fluctuation. It is estimated that this increases the cost of the original clearing $12 to $15 per acre, but the annual maintenance cost is reduced from $5 or $6 to about $0.50 to $1.50 per acre and also results in more thorough removal of vegetation.

A project for diking and dewatering an extensive shallow area in the Wheeler Wildlife Refuge was begun jointly by the U. S. Fish and Wildlife Service and the Authority. Water control structures have been completed on three outlets to the river channel, but the completion of the project, including the installation of a pumping plant, is deferred subject to a test by filling the reservoir and determining whether or not seepage through solution channels in the underlying limestone formation would result in excessive pumping.

A study which was prepared recommends a comprehensive malaria control program for the Kentucky Reservoir including permanent shoreline improvements in the problem areas before impoundage and larvicidal operations. The major features of the proposed program have been approved, including drainage on land to be purchased by the Authority above the normal pool elevation, several diking and dewatering projects, and filling of an extensive flat area in the Kentucky Reservoir. The last is the largest area proposed for this method in the Kentucky Reservoir and similar treatment of other areas will be contingent upon the experience with methods and costs gained on this project. Consideration is also being given to restricting use of land within one mile of the shoreline to daytime occupancy in a relatively large section of the reservoir as a malaria control measure.

Mosquito Proofing

The house mosquito-proofing project was continued in the central part of the Wheeler reservoir where this secondary approach to malaria control has been indicated in view of a difficult mosquito problem in the reservoir, as well as some natural breeding places outside the reservoir.

The initial work done in 1938 embraced approximately 100 houses. This was increased to approximately 350 in 1939 and to 707 houses in 1940. During the past summer 220 additional houses were added to the project, making a total of 927 houses. This

mosquito proofing has been applied in the one-mile zone of approximately 266 miles or 25 per cent of the total of 1,062 miles of shoreline for the whole of the Wheeler Reservoir. The houses have been maintained for a reasonable expenditure through making a complete repair each year. It is estimated that this thorough repair with replacements of screen doors, as required, will perpetuate the work without having to figure on a complete new rescreening at any time.

Malaria surveys and other observations to date indicate mosquito proofing, under the conditions prevailing in the Wheeler Reservoir, to be a very effective secondary approach to malaria control. All of the work has been handled by contract by the Alabama State Health Department.

Malariology and Research

From midsummer until the end of the season of propagation of *Anopheles quadrimaculatus*, higher levels of anophelism were observed during the summer of 1941 than ever before in the Tennessee Valley.

In spite of this circumstance, the evidence collected to date indicates there was no unusual prevalence of malaria in the Tennessee Valley except in a few isolated situations in upper East Tennessee. Malaria surveys which were undertaken in October have not yet been completed insofar as laboratory examination of blood films is concerned. In the few instances where survey data are complete, even in situations not protected by mosquito proofing, declining rates have been observed as compared with those for 1940.

During the year, research was intensified on the immunology of malaria, the metabolism and chemical structure of malaria parasites, and the chemotherapy of malaria. This work is being done through a cooperative research program with the University of Tennessee College of Medicine. Biological investigations were continued with special reference to Anopheles ecology.

Transactions of the

NATIONAL MALARIA SOCIETY

1941

Meeting conjointly with the Southern Medical Association

Officers

Honorary Chairman..........Dr. L. O. Howard, Washington, D.C.

Chairman..........Dr. J. N. Baker (deceased), Montgomery, Ala.

Chairman-Elect..........(Mr.) John H. O'Neill, New Orleans, La.

Vice-Chairman..........(Mr.) W. H. W. Komp, Ancon, C. Z.

Secretary-Treasurer..........Dr. Mark F. Boyd, Tallahassee, Fla.

Tuesday, November 11, 9:00 *a.m.*

The National Malaria Committee convened in joint session in the St. Louis Municipal Auditorium with the Sanitary Engineers' and Sanitation Officers' Section, Southern Branch, American Public Health Association, under the chairmanship of Mr. W. H. W. Komp.

The address scheduled to have been delivered by the chairman, Dr. J. N. Baker, was omitted, owing to his untimely death a few days before the meeting.

Wednesday, November 12, 9:00 *a.m.*

The business meeting of the twenty-fourth annual session of the National Malaria Committee, was called to order in the St. Louis Municipal Auditorium by Mr. W. H. W. Komp.

The minutes of the 1940 meeting held in Louisville, Kentucky, were approved as published in the January, 1941 issue of the Southern Medical Journal.

The Secretary-Treasurer reported a total of 184 active, and 20 honorary members, a total of 204, and cash receipts of $279.92; which added to the 1940 balance of $214.17 less disbursements of $129,25, leaves a current balance of $364.94.

The Chairman then appointed the following temporary sub-

committees, viz: Auditing—Mr. H. W. Van Hovenberg, Mt. Pleasant, Texas, Doctor E. H. Hinman, Wilson Dam, Alabama, and Mr. John H. O'Neill, New Orleans, La. Nominating—Dr. Justin Andrews, Atlanta, Georgia, Mr. C. Robert Coatney, Bethesda, Md., and Mrs. E. B. Johnson, New Orleans, La.

Dr. L. L. Williams, acting on behalf of the Sub-committee on Resolutions, presented a series of nine motions previously circulated to members by which seven changes were effected in the constitution and two in the by-laws through amendment. Two of the proposed changes were slightly altered before adoption. The constitutional amendments:

a) Change the name of the organization to the National Malaria Society;

b) Define the qualifications for honorary membership;

c) Increase the annual dues to three dollars, two of which are set aside for publication purposes;

d) Repeal the provisions for life membership;

e) Create a representative to the council of the American Association for the Advancement of Science to be appointed by the President.

f) Change the designation of certain officers so that the word president is employed where chairman was used;

g) Create an editorial board of three members, and describe their terms of office, and the funds available to them for publication purposes.

The amendments to the by-laws are additions and cover:

h) The powers and duties of the editorial board.

i) Authorizes appointment of state committees to conduct local essay contests among school children.

Individual motions of adoption for each unanimously carried.

Reports were received from the following scientific subcommittees, which were accepted and filed, viz:

Medical Research, presented by Dr. J. C. Schwartzwelder, New Orleans, La.; Entomology, by Mr. Stanley Carpenter, Camp Robinson, Arkansas; Statistics, by Dr. Justin Andrews, Atlanta, Ga.;

Engineering, by Mr. David Lee, Jacksonville, Fla.; Industrial Relations, by Mr. H. W. VanHovenberg, Mt. Pleasant, Texas, and Epidemiology, by Doctor E. C. Faust, New Orleans, La.

A motion carried adopting the recommendations of the Subcommittee on Engineering, which further prescribed that this committee shall assume the responsibility for collecting and distributing cost data on drainage and larvicidal operations.

Reports of malaria control activities from the following states were submitted, viz: Virginia, by Mr. R. E. Dorer, Norfolk, Va.; South Carolina, by Dr. G. E. McDaniels, Columbia, S. C.; Georgia, by Mr. Justin Andrews, Atlanta, Ga.; Florida, by Mr. David Lee, Jacksonville, Fla.; Kentucky, by Mr. G. E. Quinby, Louisville, Ky.; Missouri, by Mr. W. S. Johnson, Columbia, Mo.; Tennessee, by Dr. W. C. Williams, Nashville, Tenn.; Mississippi, by Mr. Nelson H. Rector, Jackson, Miss.; Louisiana, by Mr. H. J. Darcey, Oklahoma City, Okla.; Supplemental reports were also received, viz: from the U. S. Public Health Service, by Mr. J. L. Robertson, Jr., Memphis, Tenn:; the International Health Division of the Rockefeller foundation, by Dr. Mark F. Boyd, Tallahassee, Fla.; and from the Tennessee Valley Authority, by Dr. E. L. Bishop, Chattanooga, Tenn.

On behalf of the resolutions subcommittee, Dr. L. L. Williams submitted appropriate resolutions pertaining to the demise of the following members, Dr. J. N. Baker, Mr. Bruce Mayne, and Mr. George Hazlehurst, which were adopted. Resolutions of thanks to the St. Louis Medical Society were also adopted.

On consideration of new business, Mr. Van Hovenberg inquired whether the resolutions subcommittee had prepared recommendations relating to certain matters referred to it at the business session on November 15, 1940. The subcommittee not being represented at the time, the chairman referred the inquiry to the subcommittee.

Mr. W. H. W. Komp called attention to the desirability of enlarging the mosquito collections in the U. S. National Museum by the more frequent deposit of local collections, and urged cooperation with this institution.

The subcommittee on auditing reported that their examination of the secretary-treasurer's records and accounts agreed with his report, and moved its adoption, together with the allowance of an honorarium of $50.00 to his secretary. The motion carried.

The subcommittee on nominations offered the following slate of nominations, viz:

Honorary President—Dr. L. O. Howard, Washington, D.C.

President—Mr. John H. O'Neill, New Orleans, La.

President elect—Colonel J. S. Simmons, Washington, D. C.

Vice President—Dr. H. W. Brown, Chapel Hill, N. C.

Secretary-Treasurer—Dr. Mark F. Boyd, Tallahassee, Fla.

There being no nominations from the floor, a motion was adopted directing the secretary to cast a unanimous ballot for the above nominees.

The Society then adjourned to 9:00 a.m. Thursday.

Thursday, November 13, 9:00 *a.m.*

The National Malaria Society convened in joint session with the American Society of Tropical Medicine in the St. Louis Municipal Auditorium, with Dr. E. C. Faust, President-elect of the American Society of Tropical Medicine and Mr. W. H. W. Komp, President of the National Malaria Society, presiding.